A Brief History of

Human Waste Disposal

-- and its possible Future

Part 1. Cesspits & Outhouses
Part 2. Toilets & Water Carriage
Part 3. Sewerage
Part 4. Sewage Treatment
Part 5. Wastewater Treatment
Part 6. The Future:
Wastewater Reclamation

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Tom O'Connor, PE

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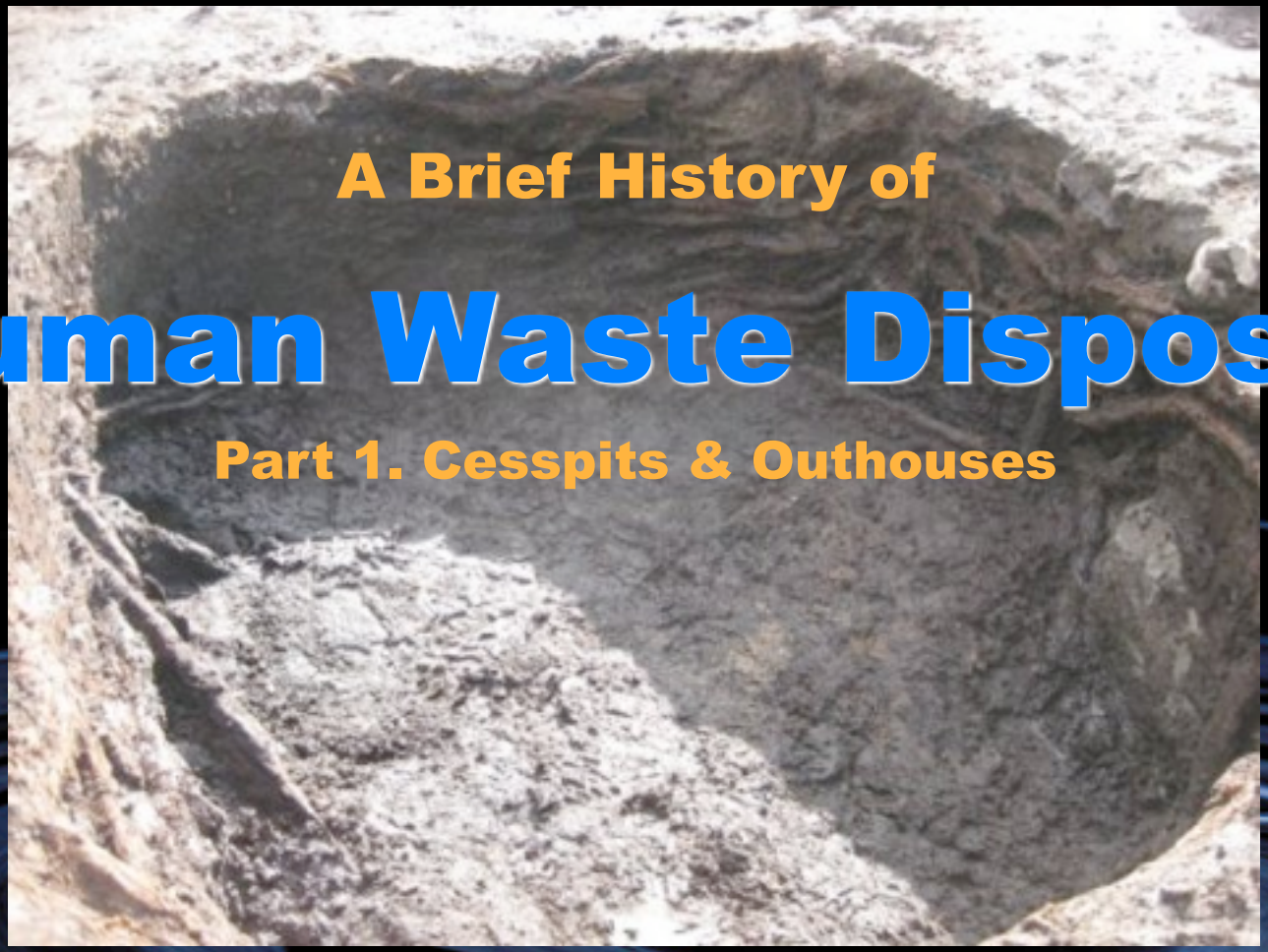

A Brief History of

Human Waste Disposal

Part 1. Cesspits & Outhouses

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Medieval Woodcut

Chamber Pot to Gutter Waste Disposal System

Rats, Pigs

Black Death

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England: ~1850

Sewers - Old English word for *'Seaward'*

Cesspit beneath floors; overflow to streets
London (1810): 200,000 cesspits/ 1 million

Windows sealed against *'Night Air', miasma*
a mix of coal smoke and sulfurous fog

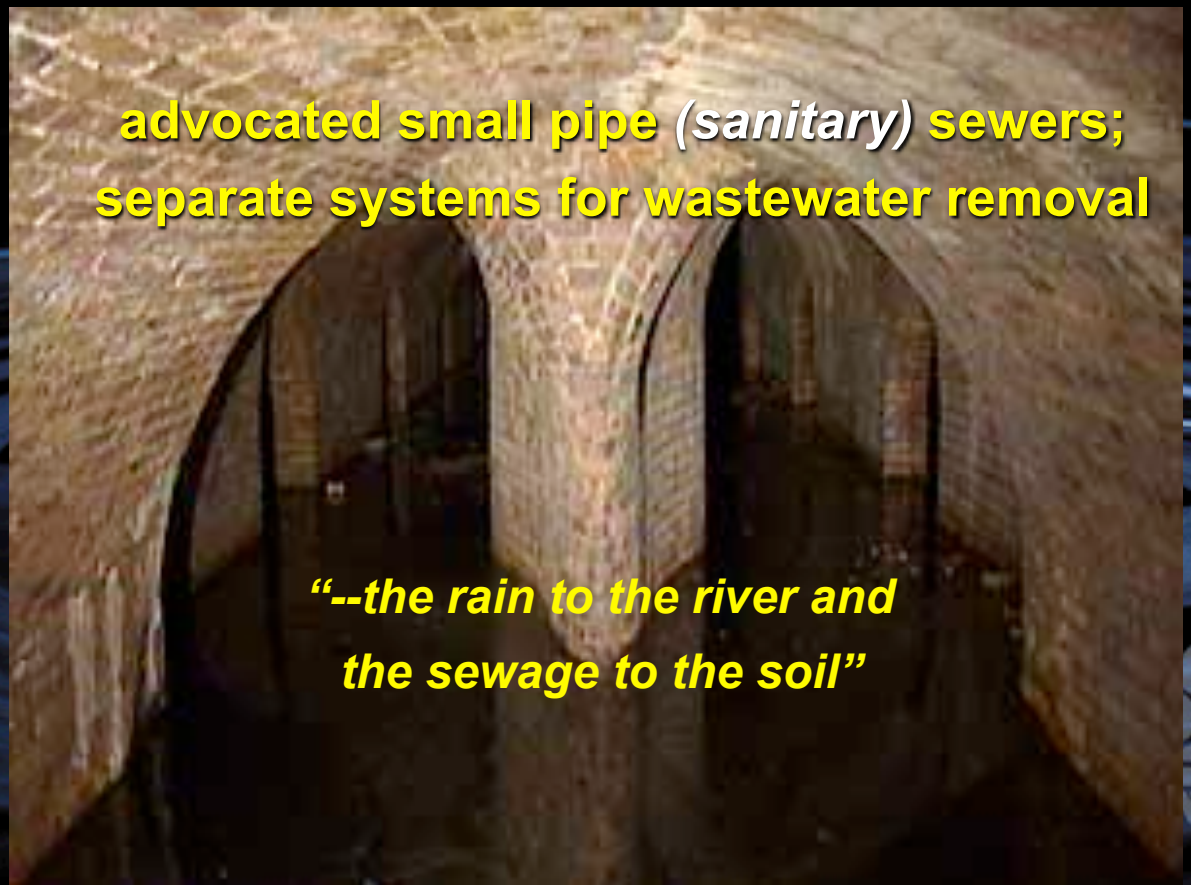
Asphyxiation common due to hydrogen sulfide and oxygen deficiency; methane explosions

Reclaimed *'Night Soil'* used as crop fertilizer; small children harvested cesspit wastes

Edwin Chadwick 1800-1850

Report of the *Poor Law Commissioners* on an

Inquiry into the Sanitary Condition of the Labouring Population of Great Britain, 1842:


advocated small pipe (sanitary) sewers;
separate systems for wastewater removal
"--the rain to the river and
the sewage to the soil"

Waste Disposal to 1850

Chamber Pots into Street Gutters

Cesspits, Cesspools under Houses:

Seepage, Overflow to Streets

Pit Privies and Soil Absorption

Sewage Farming 1840 - 1890

Broad Irrigation to Fields:

Poor Law Commissioners of England
1842

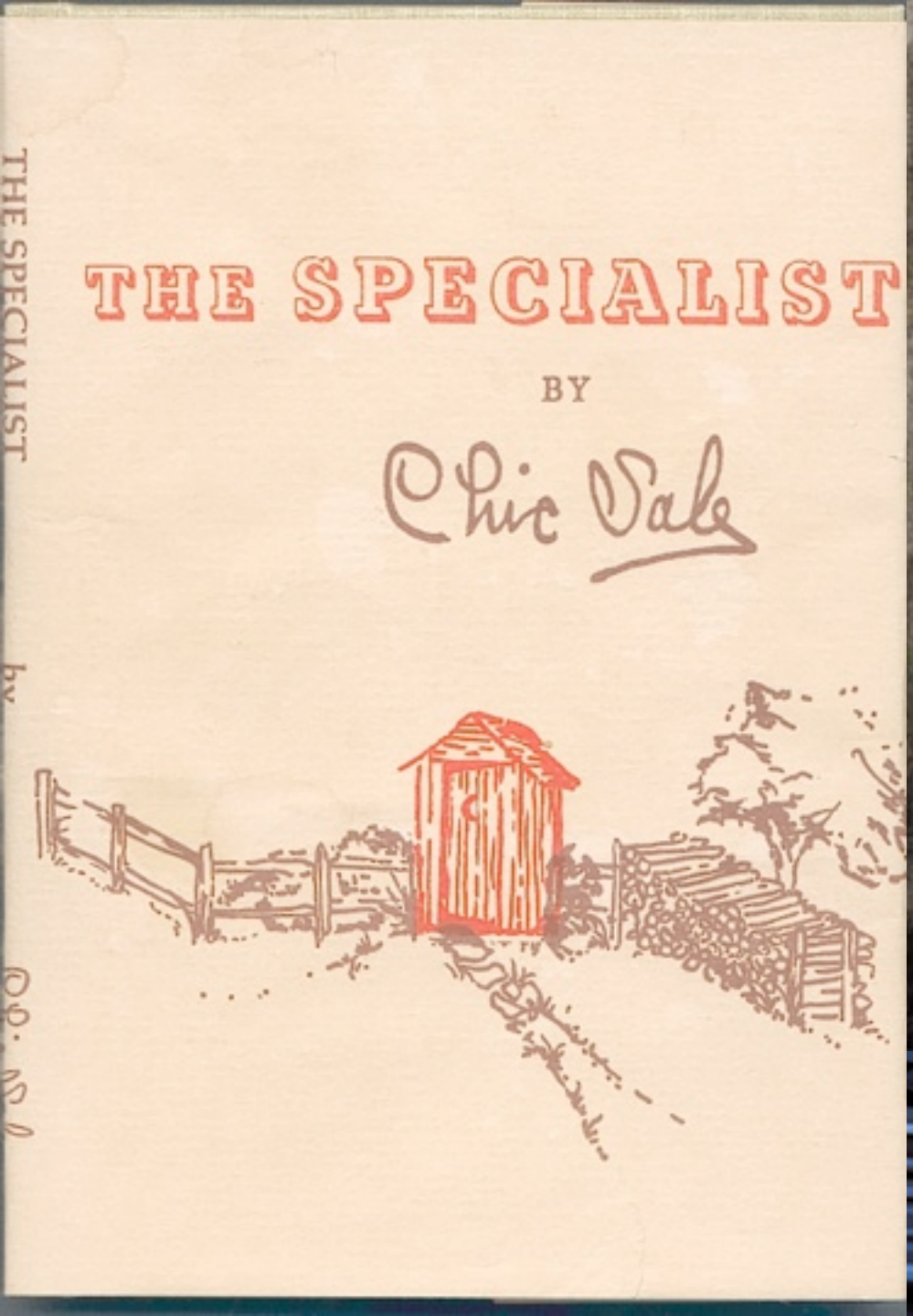
State Insane Asylum, Augusta, Maine
1875

(abandoned: resulted in clogged, stinky soils)

Western (arid) U.S. 1890

Peas, beans, tomatoes, corn, cabbage, alfalfa, fruit, ...

U.S. Sewage Farming ended ~1930


THE SPECIALIST
BY
Chic Sale
THE SPECIALIST by Chic Sale

Charles (Chic) Sales
documents the emergence of
The Specialist
(1929)
'... dig her deep and dig her wide...'
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Earth-Pit Privy

Design Criteria:

6 feet deep

50 cubic ft.

'.. lean-to roof has two less corners for the wasps to build their nests in..'

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Two-Storied Outhouse

for two-storied houses with two families

Design Capacity, Per Person
feces: 0.2 kg /day
urine: 1 liter /day

Unflattering metaphor for President Reagan's *'trickle down'* theory

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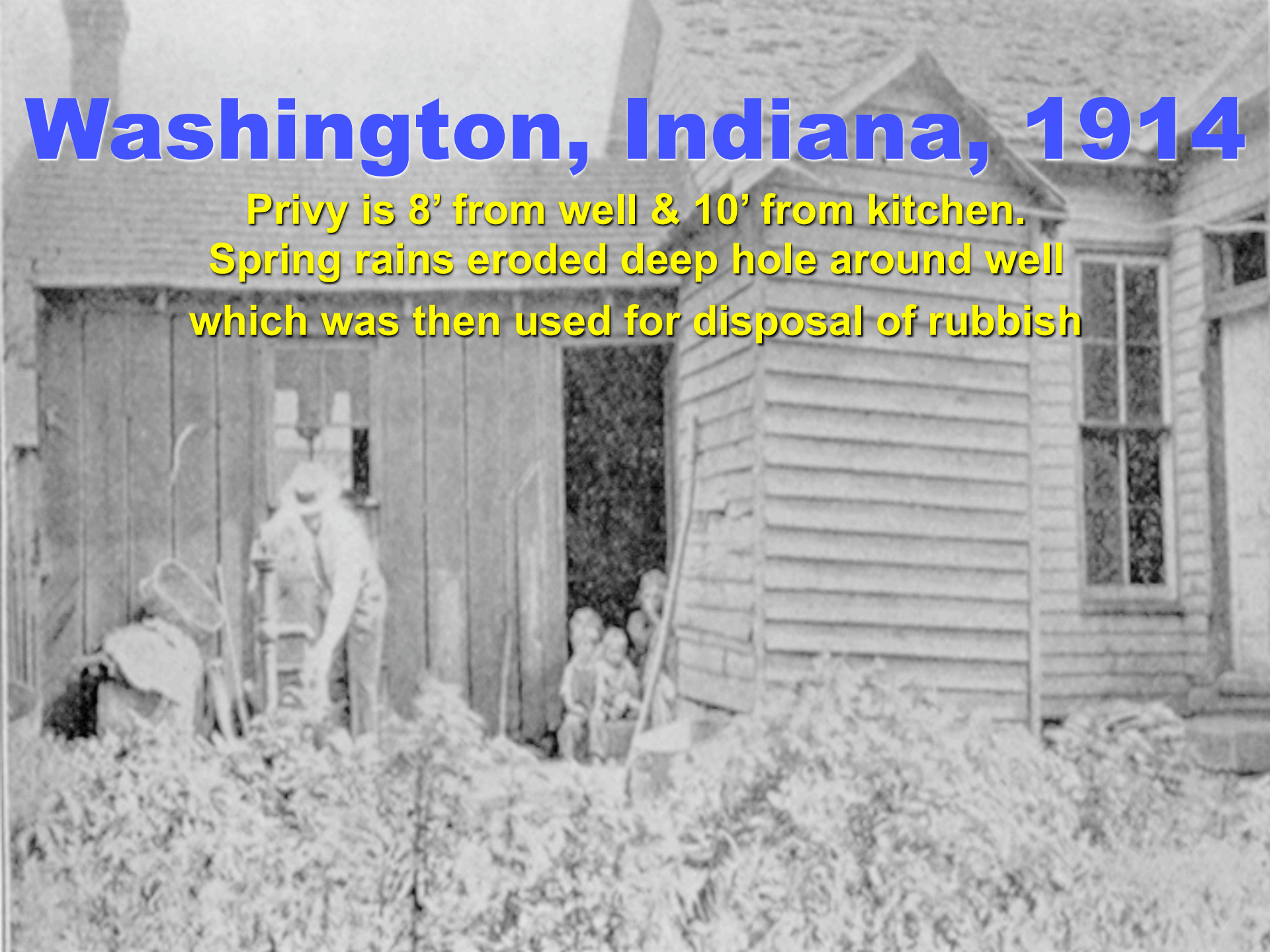
Washington, Indiana, 1914
Privy is 8’ from well & 10’ from kitchen.
Spring rains eroded deep hole around well
which was then used for disposal of rubbish

Sears Catalogs, Rags, Newspapers & Corn Cobs

packaged toilet paper,
first introduced in 1857,
sold poorly.

Scott paper on a roll
succeeded in 1890.

2000: 150 rolls/yr,
$40 / person

scented, recyclable

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Southeast Missouri Farms Project

1938

laborers construct, load outhouses for delivery to Missouri homesteads

Privy with a View

On August 29, 2007, the highest outhouse in the continental U.S., atop Mount Whitney, was removed. Two other outhouses, in the Inyo National Forest, were closed due to the expense and danger involved in transporting out large sewage drums via helicopter.

Alaska 2010

Outhouse Capital of the United States

"Ventilation?

Every Outhouse in Alaska has bullet holes ..."

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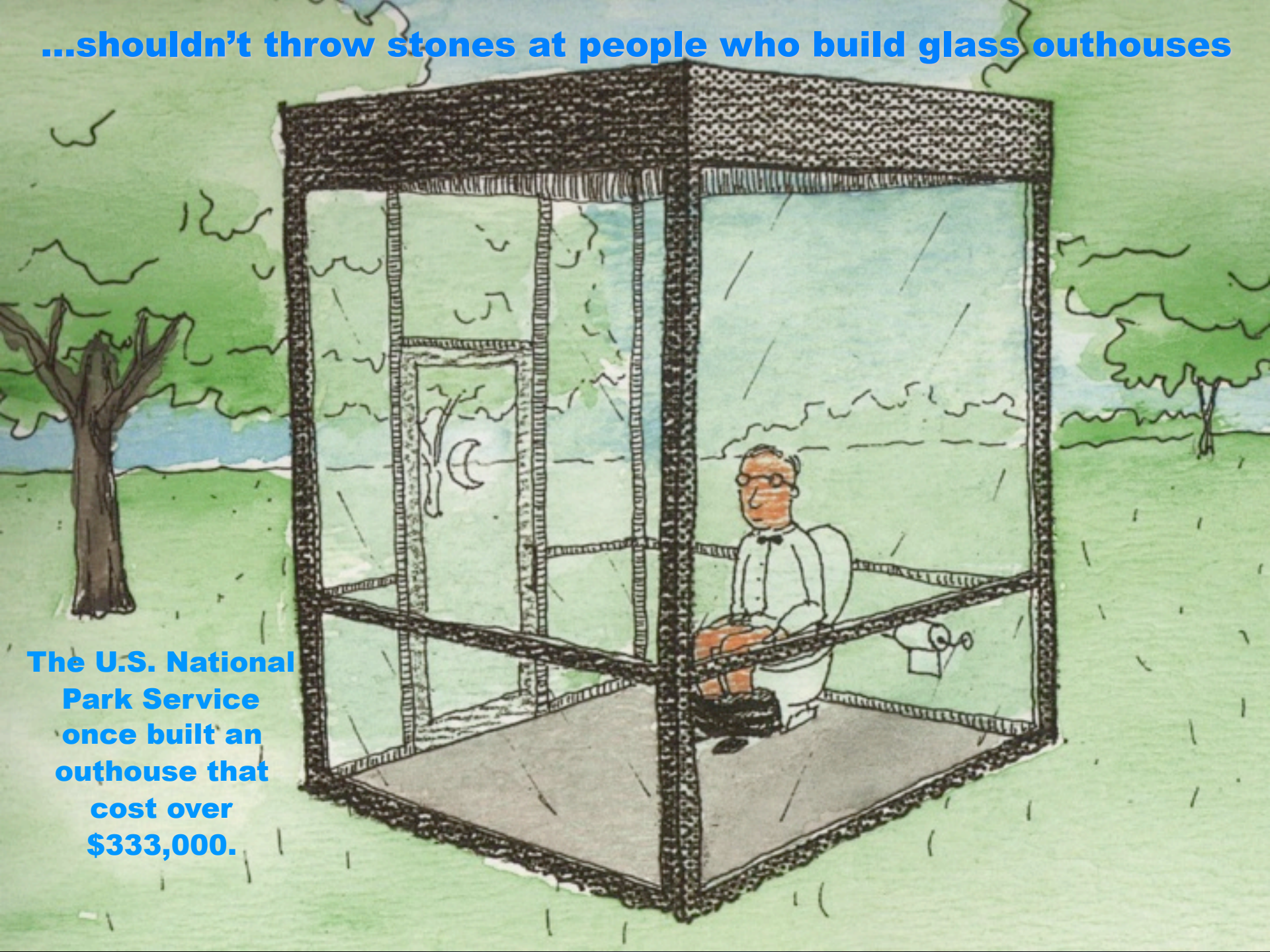
Wasilla, Alaska Outhouse

New Zealand 2004 - Loo with a View

SUPER
LOO
SUPER
LOO

...shouldn't throw stones at people who build glass outhouses



The U.S. National Park Service once built an outhouse that cost over $333,000.

U.S. Population becomes Urban

1910: 92 million

38% sewered

89% untreated

1968: 197 million

70% sewered

89% treated

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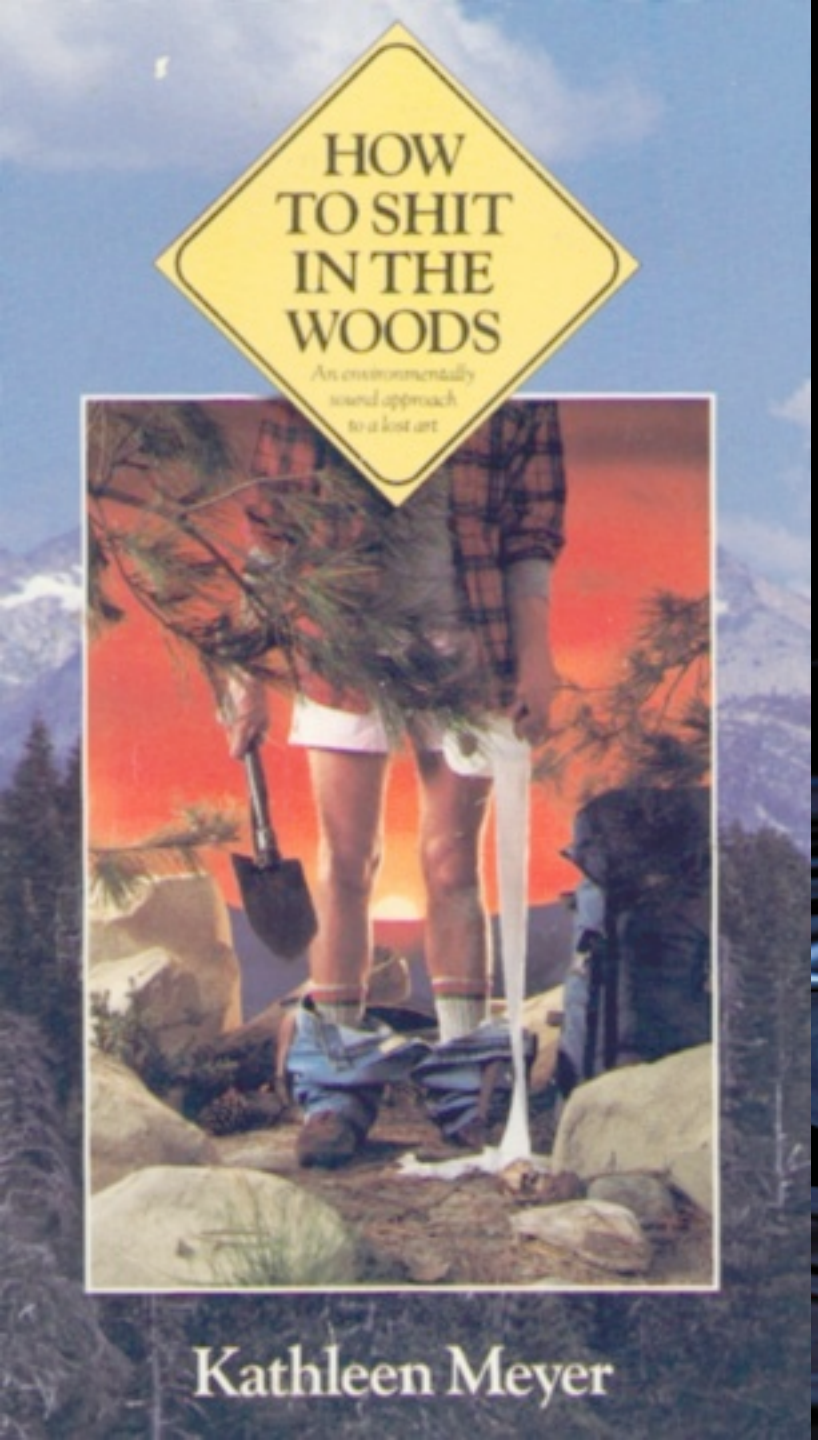

How quickly we forget!

2001: Enlightening The Trekker

Dig a Hole

Plastic Bag as Chamber Pot

Don't Use the Flora

Pack out the Paper

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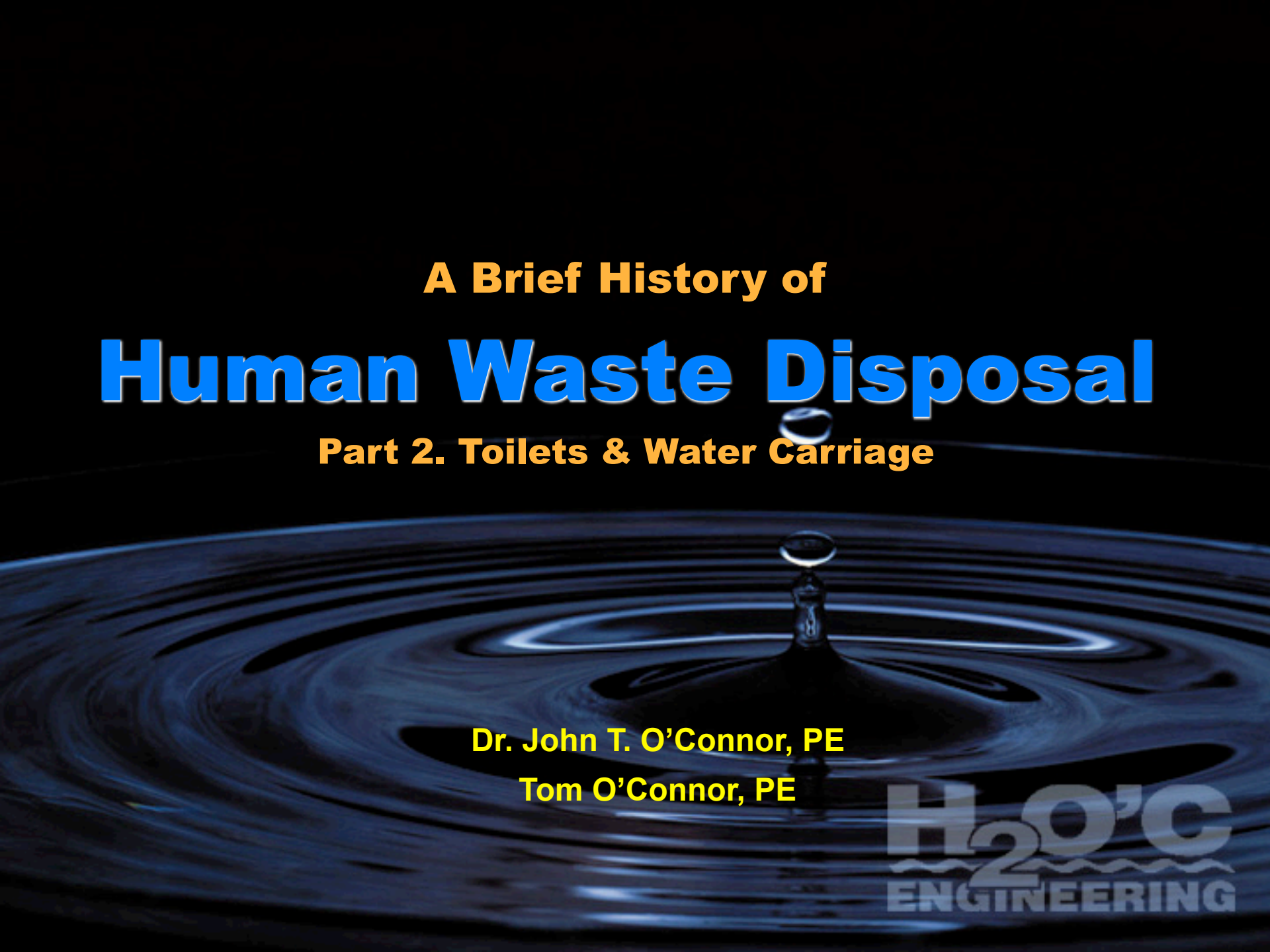
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Human Waste Disposal
Part 2. Toilets & Water Carriage
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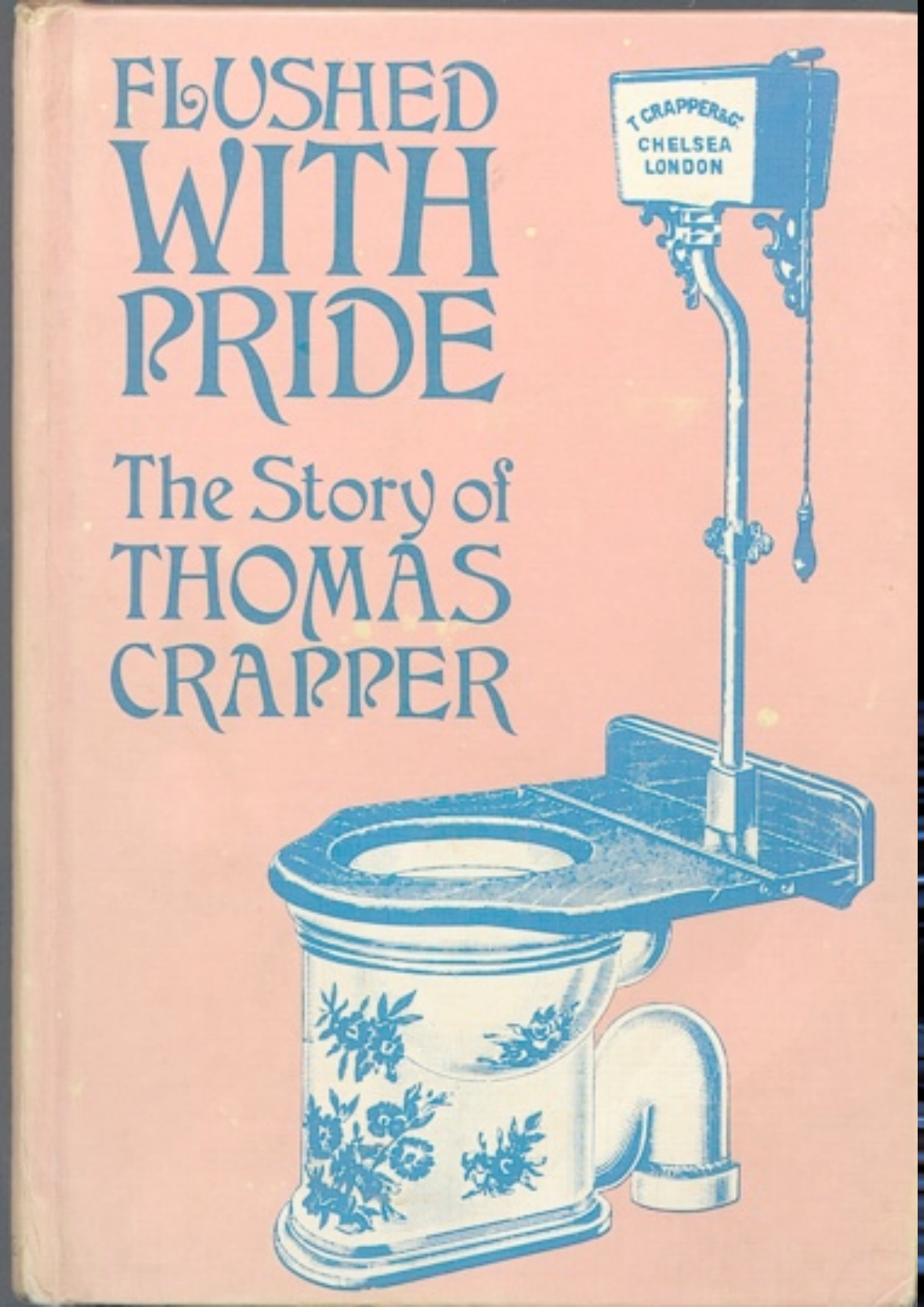
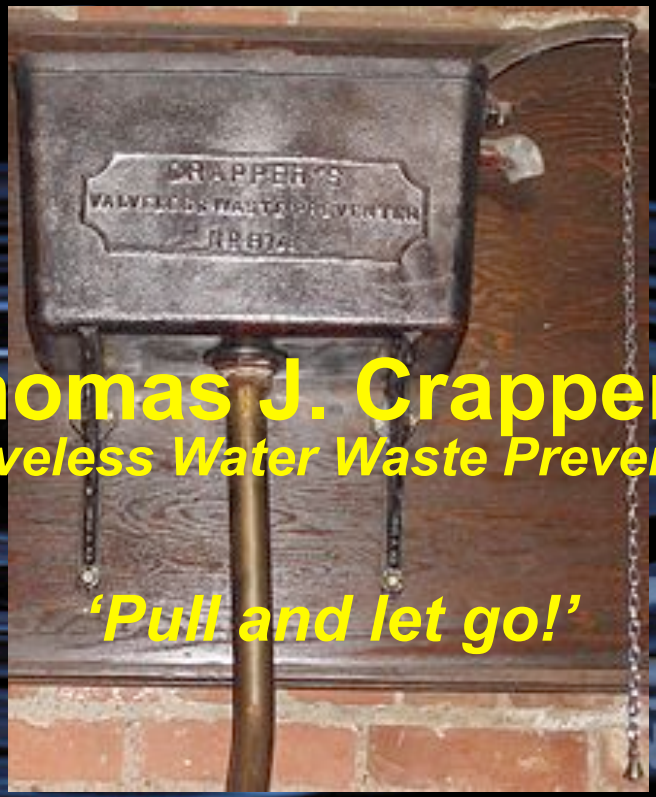


Indoor Plumbing
circa 1900

to eliminate:
disease, fumes, explosions



Thomas J. Crapper's
Valveless Water Waste Preventer

'Pull and let go!'

Telegrams CRAPPER CHELSEA Telephone No. 357 Kensington

THOMAS CRAPPER & CO.,

PATENTEES AND MANUFACTURERS

OF

Sanitary Appliances.

ENGINEERS BY APPOINTMENT TO

His Majesty the King

AND

H.R.H. The Prince of Wales.

MARLBORO' WORKS, CHELSEA, LONDON, S.W.

Show Rooms and Offices:

50, 52, & 54 MARLBOROUGH ROAD, CHELSEA, S.W.

CATALOGUE AND PRICE LIST,

MAY, 1902.

(Subject to alterations without notice.)

ALL PREVIOUS ISSUES CANCELLED.

0-13-322560-7

T. Crapper, Sanitary Engineer also patented:

House Drain Ventilators

Air Pump and Smoke Generating Machines

Disconnecting Traps

Self-Rising Closet Seats

Cantilever Toilet

Flusherette Valve

Stair Treads to prevent slipping

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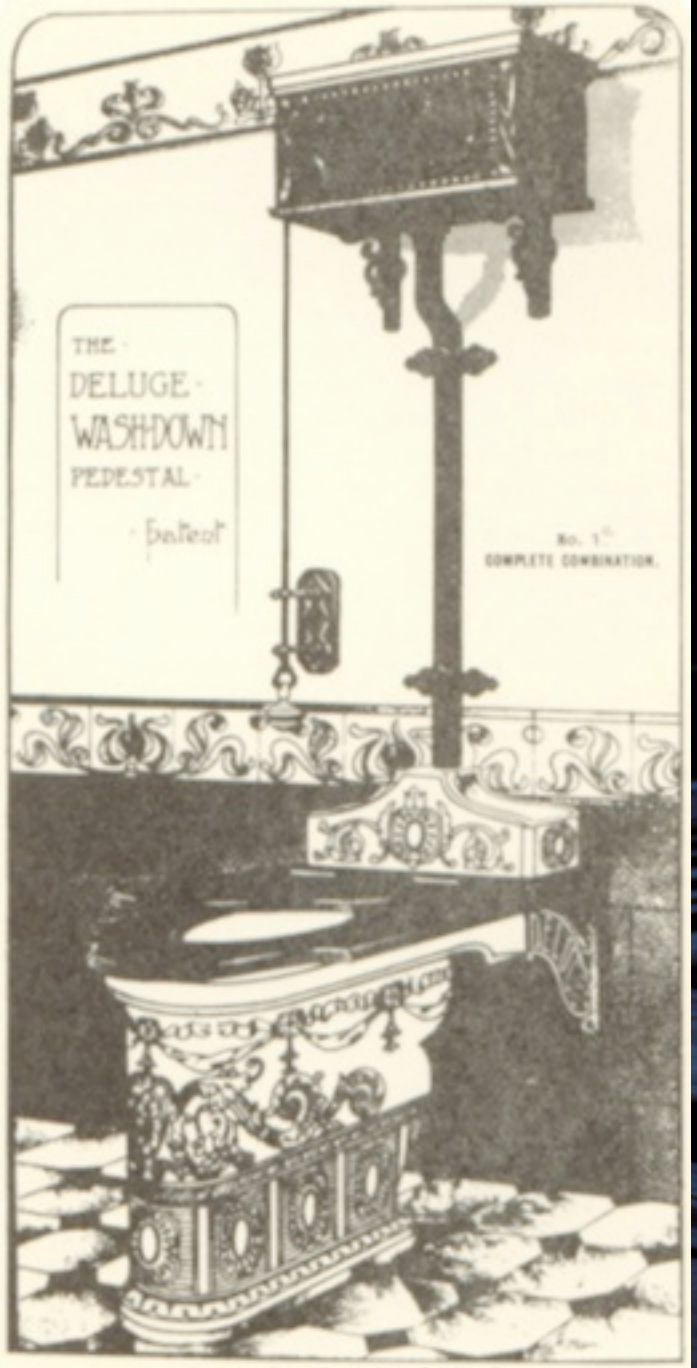

An early Twyford W.C. with siphonic cistern

Explosions, Rats & Disease

1870: 1 in 3000 died of typhoid

Waterborne Wastes required Collection Systems (Sewers)

Toilets Undermined Use of Cesspools

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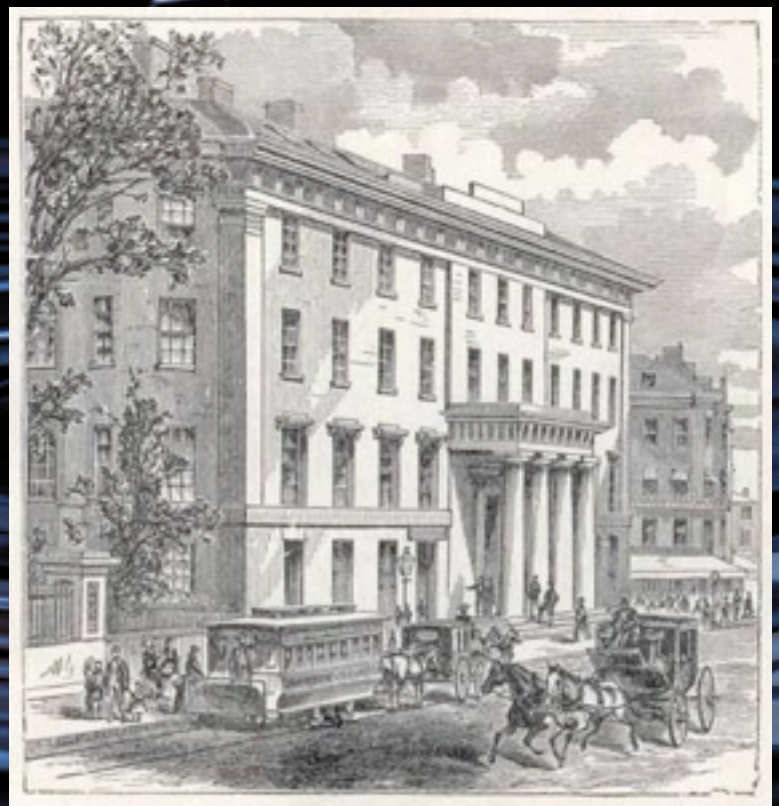
Earliest Indoor Plumbing United States

White House: 1825 – the ‘Quincy’

Tremont House (Boston Hotel): 1880s



Toilet Paper - U.S.

1857 Joseph Gayetty - therapeutic paper with Aloe

500 sheets for 50¢

1890 Scott Paper Co. - tissue on a roll -1000 sheets

"over 65% of middle-aged men and women suffer from some sort of rectal disease"

"Sani-tissue and Waldorf are famous bathroom tissues specifically processed to satisfy the three requirements doctors say toilet tissue must have to be safe: absorbency-softness-chemical purity"

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Hello, Toto

‘Faulty wiring’ leading to smoke and fires prompted Toto, Japan’s leading toilet maker, to offer free repairs on 180,000 of their popular series Z electric bidet toilets.

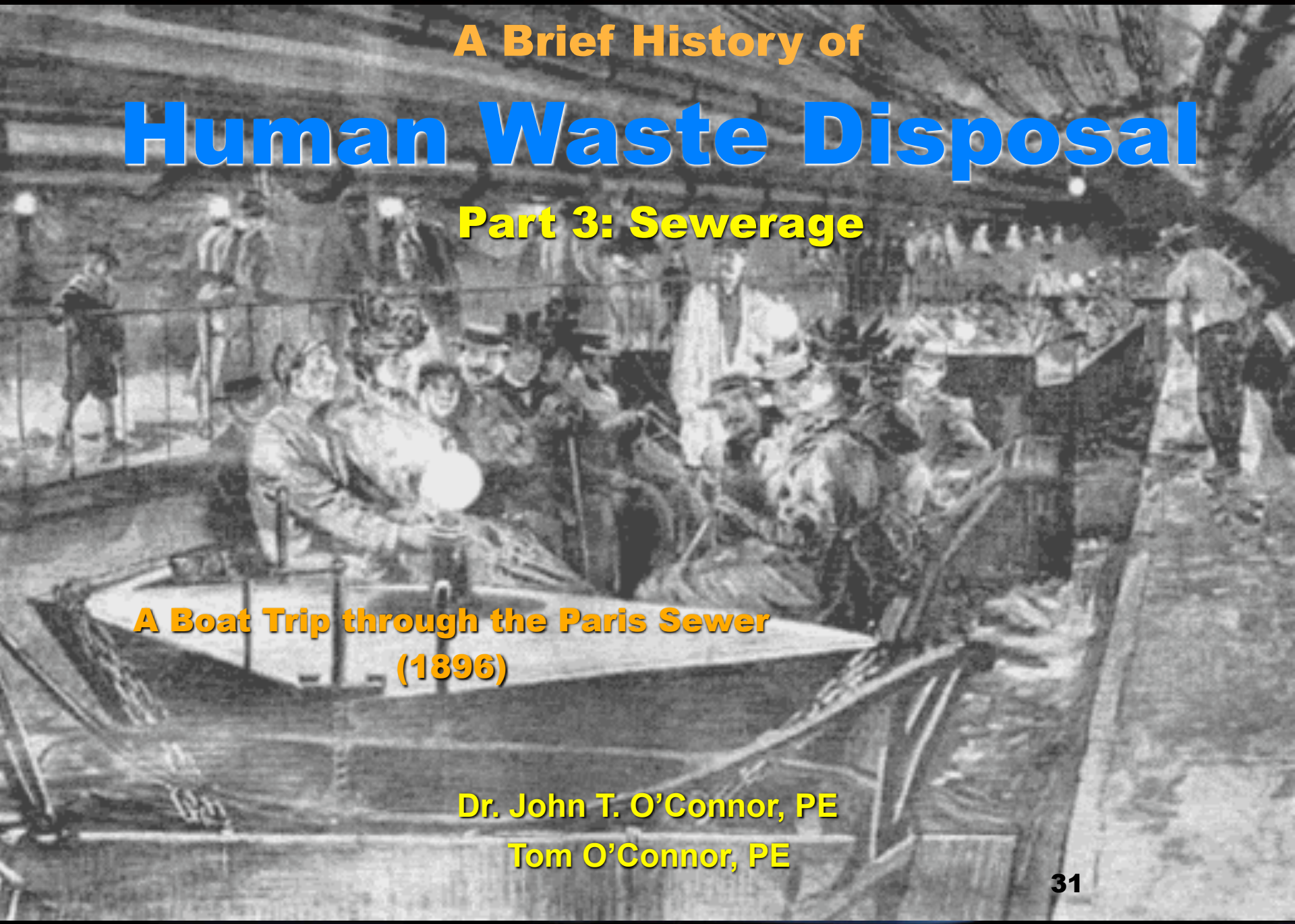
The $2,000 “Z” features a pulsating massage spray, a power dryer, built-in-the-bowl deodorizing filter, a ‘Tornado Wash’ flush and a lid that opens and closes automatically.

BanZai!

A Brief History of

Human Waste Disposal

Part 3: Sewerage



A Boat Trip through the Paris Sewer
(1896)

Dr. John T. O'Connor, PE
Tom O'Connor, PE

Sewer Socialists?

"Municipal Socialism" 1900-today

A Century of Sewer Construction in the U.S.:

- **disposal of wastes to sewerage found *'convenient'***
- **ample *water supplies* led to production of ever-increasing volumes of *'wastewater'***

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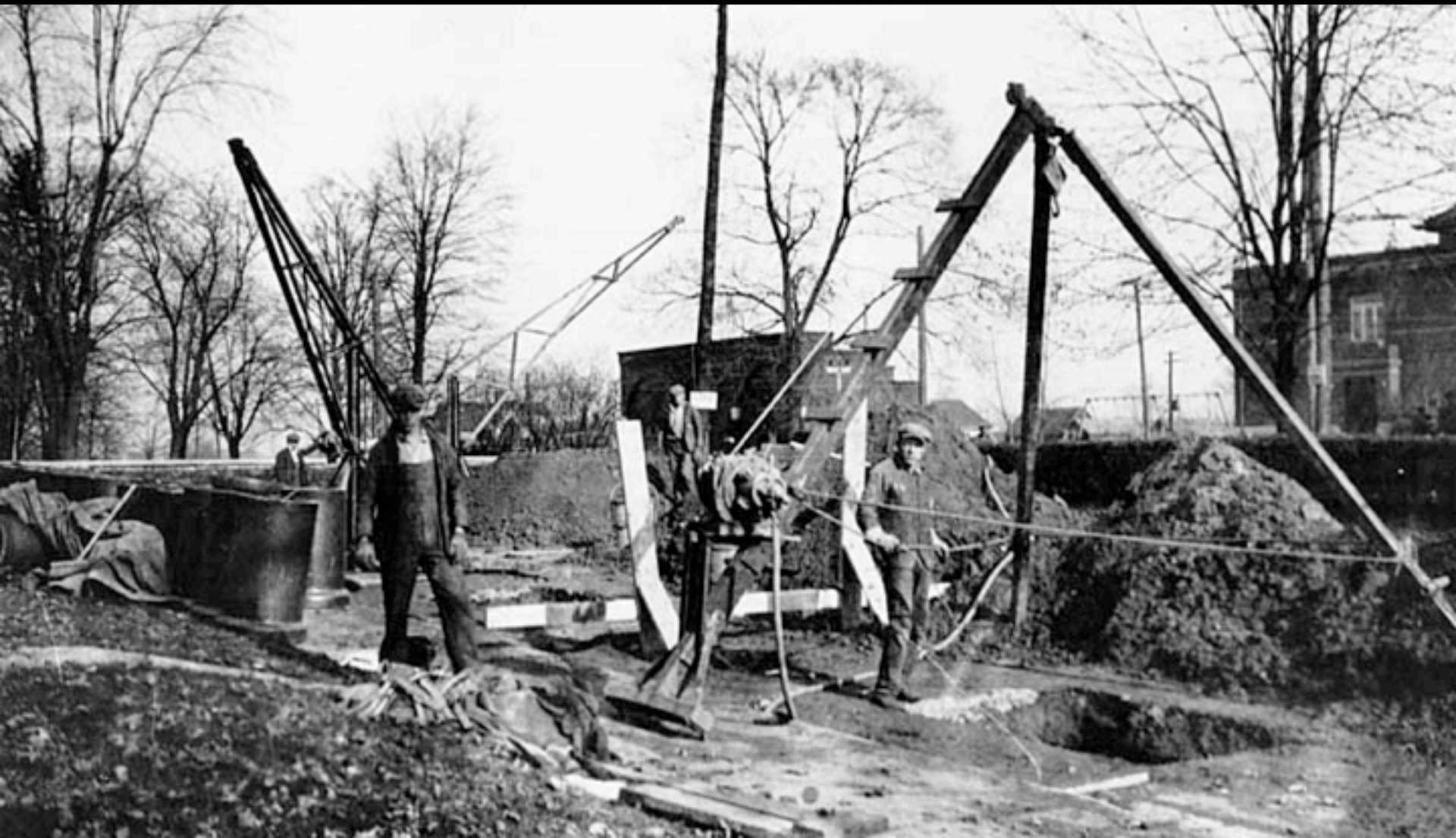
Bristol, England

Hollowed-Out Wooden Water Pipe - 500 years old

Museum of Edinburgh, Scotland

Sewer Construction - 1900



Salt Lake City to Sewer Farms 1908

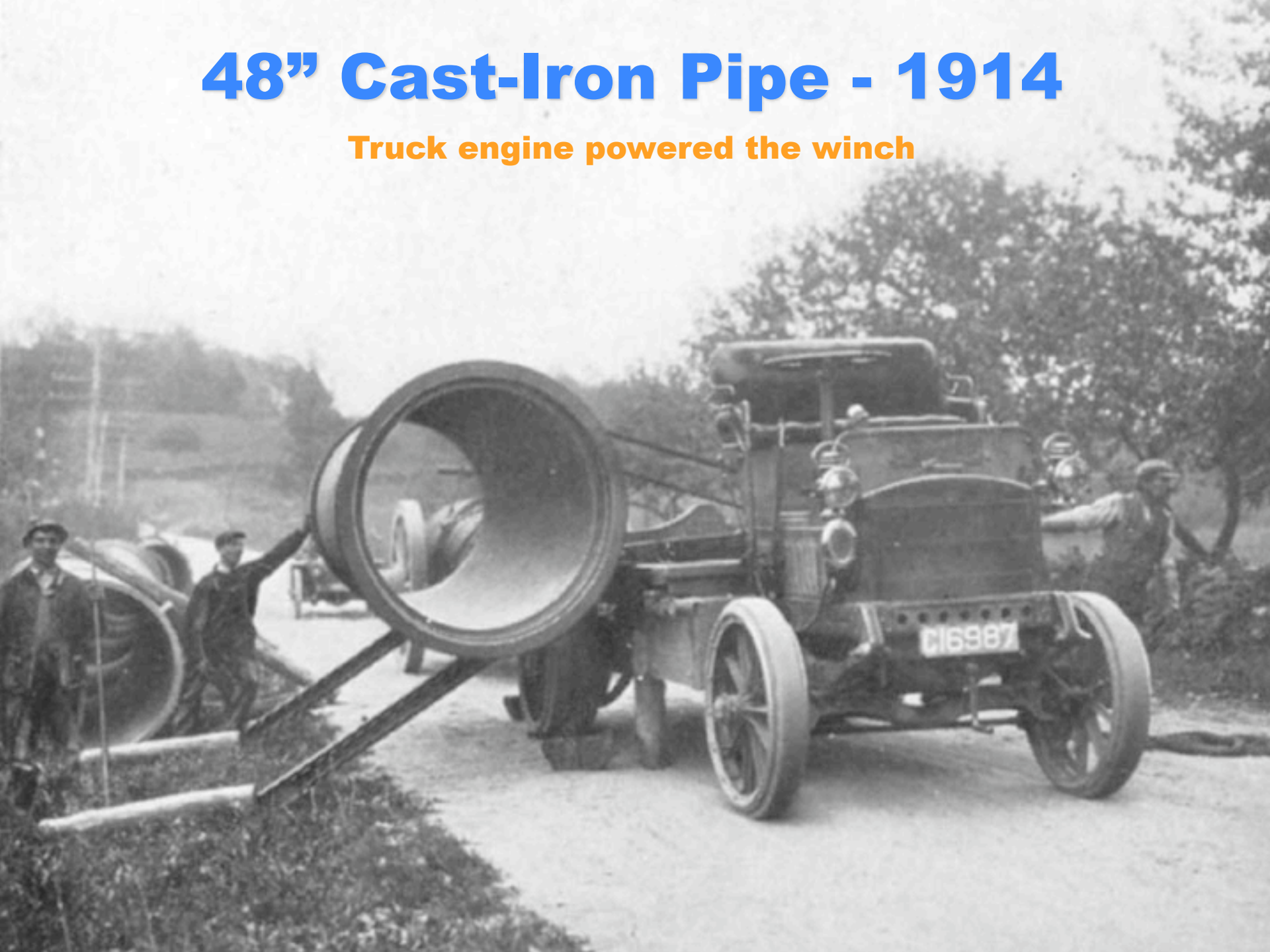
Wood Stave Pipe assembled in the trench

Sewer Construction 1900

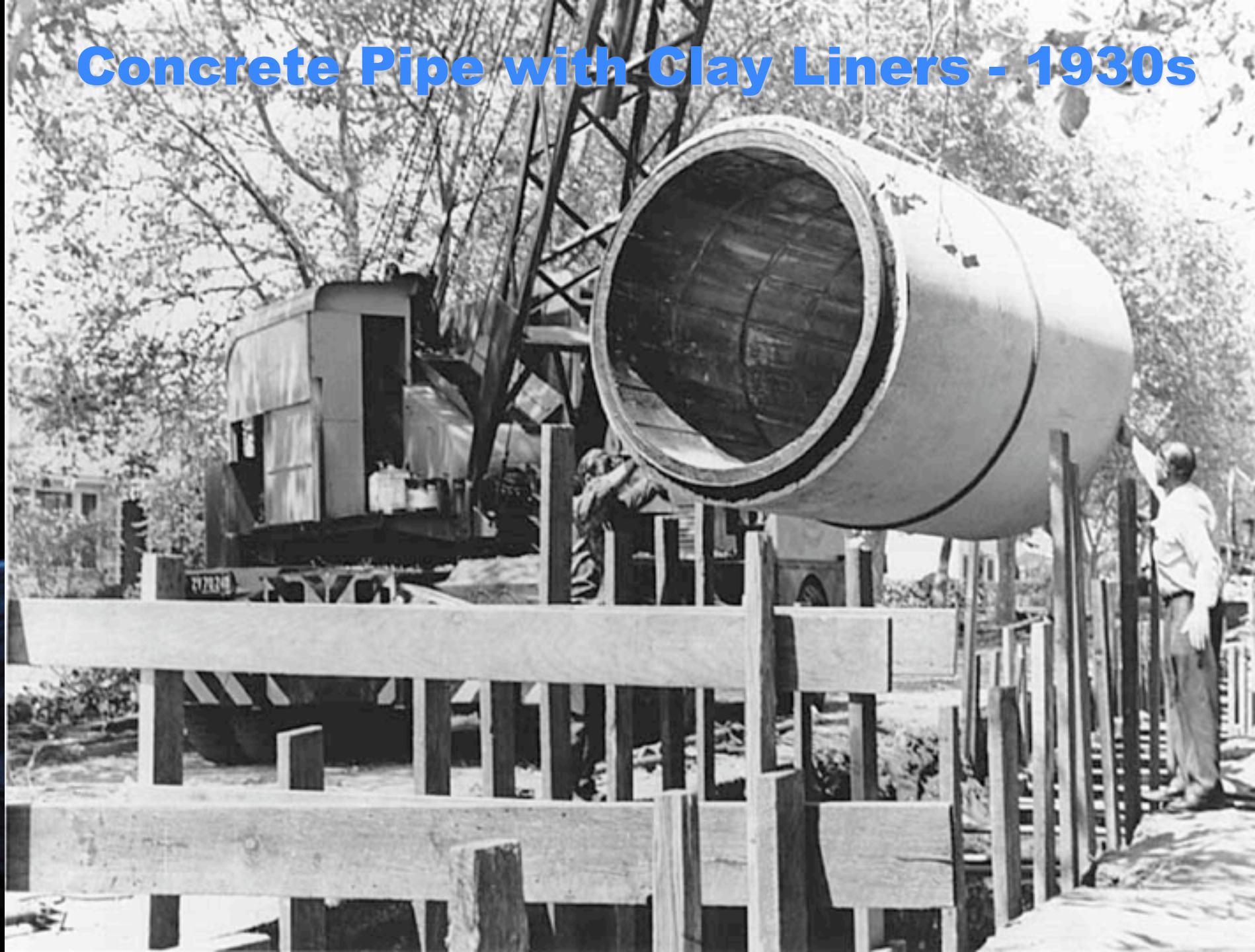
Joske's
PAP

48” Cast-Iron Pipe - 1914

Truck engine powered the winch



Concrete Pipe with Clay Liners - 1930s



Springfield, Missouri

Sanitary Sewerage Timeline

1894-1910: 41 miles - brick and clay sewers

1911-1937: 96 miles

1937-1957: 68 miles - clay pipe

1960 - vitrified clay, cast iron, rein. conc. pipe

1976 - polyvinyl chloride pipe

2010: 1,176 miles + *25 miles/year*

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Separate Sewer System

Combined Sewer System

Combined or Separate Sewers?

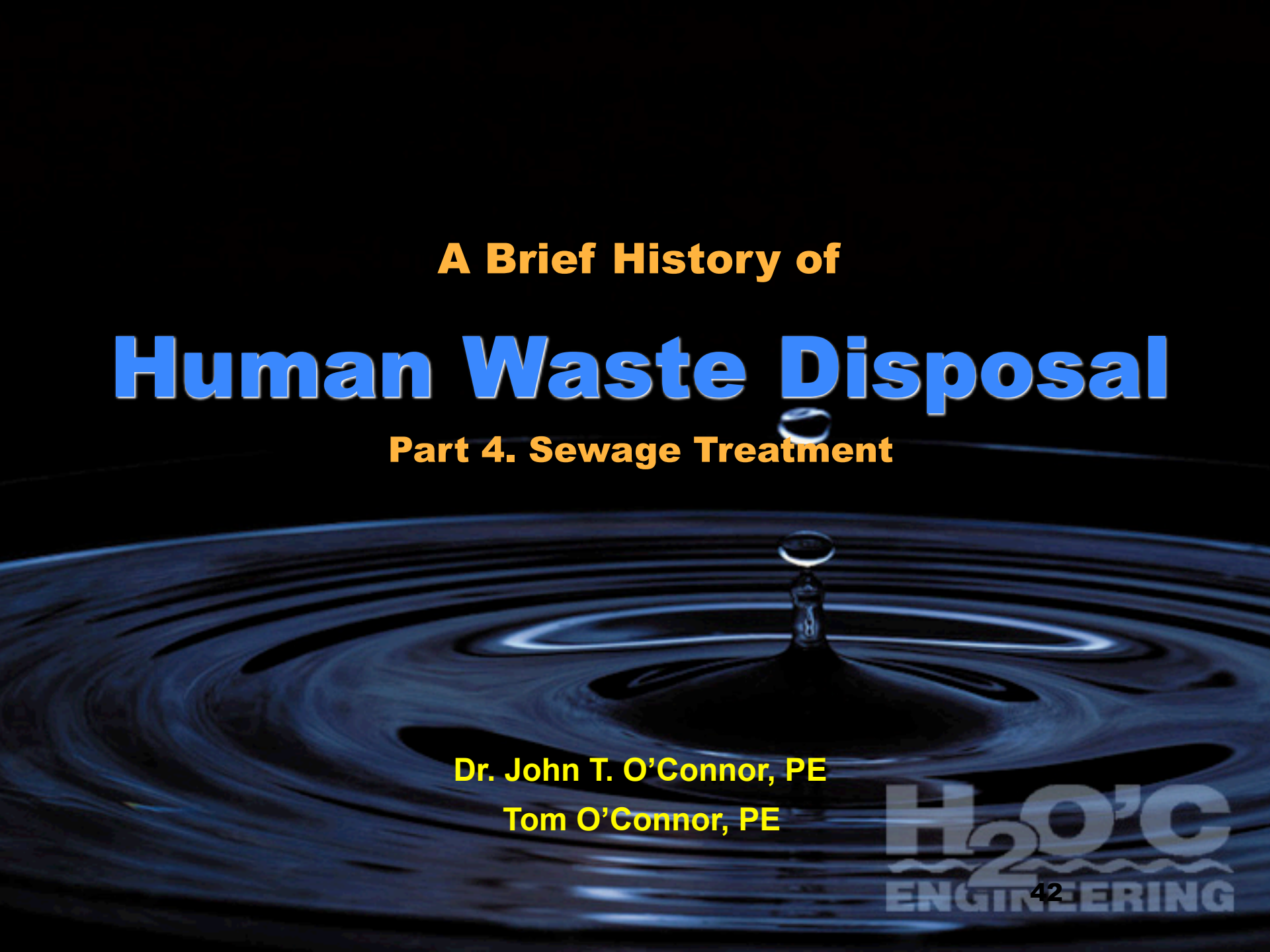
In the older parts of Kansas City, the same pipe that carried stormwater also carried sewage in a *Combined Sewer System.*

Combined Sewer Systems were common until the 1970s as wastes were simply carried to streams.

Combined Sewers were constructed because sewage treatment was not anticipated. It was thought to be more economical to build one pipe rather than two.

Costly choice, as it turns out. **Kansas City will spend $2.5 billion over 25 years to curb unauthorized overflows of untreated raw sewage.**

U.S. has ≈600,000 miles of publicly-owned sewer pipe



A Brief History of

Human Waste Disposal

Part 4. Sewage Treatment

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Tom O'Connor, PE

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Unsewered Systems

On-Site Treatment and Disposal:

Flow Range: 0.2 to 2 m^3/ day

Septic Tanks (Settling; Fermentation):

- 1 to 2 day retention; 2 meters deep
- scum, sludge removal every 6 to 12 months
- sludge to lagoons, earth-covered trenches
- *or* plowed into land after partial drying on surface
- soil absorption systems for tank overflow

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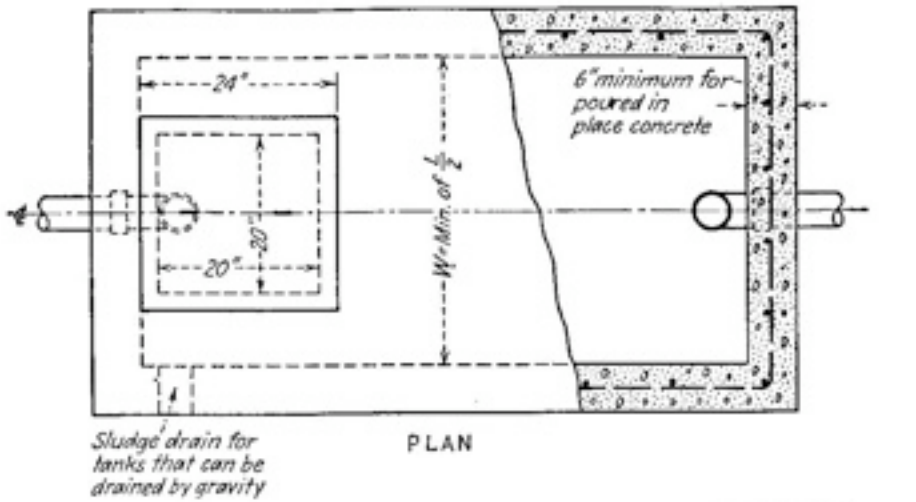

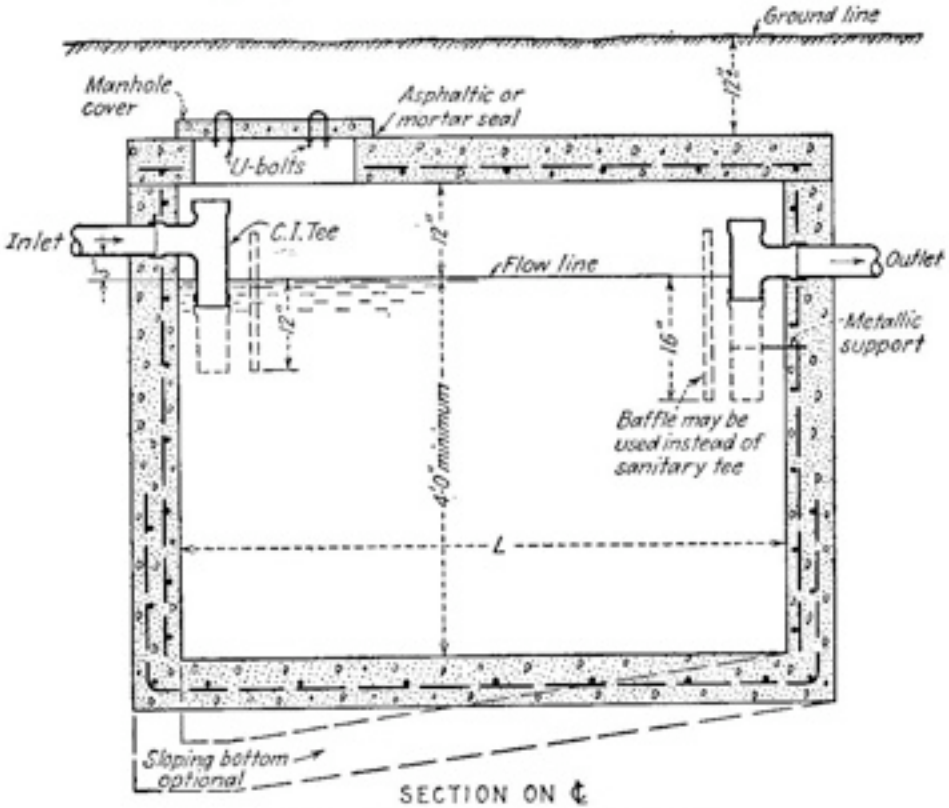

FIG. 51. A single-compartment septic tank.

Septic Tank

Unit Capacity:

4 to 16 people

500 - 2000 gallons

90 -300 cubic feet

1-3 compartments

L/W: 3/1; D: 4-6 ft.

Scum, gas baffles

Filter Vault

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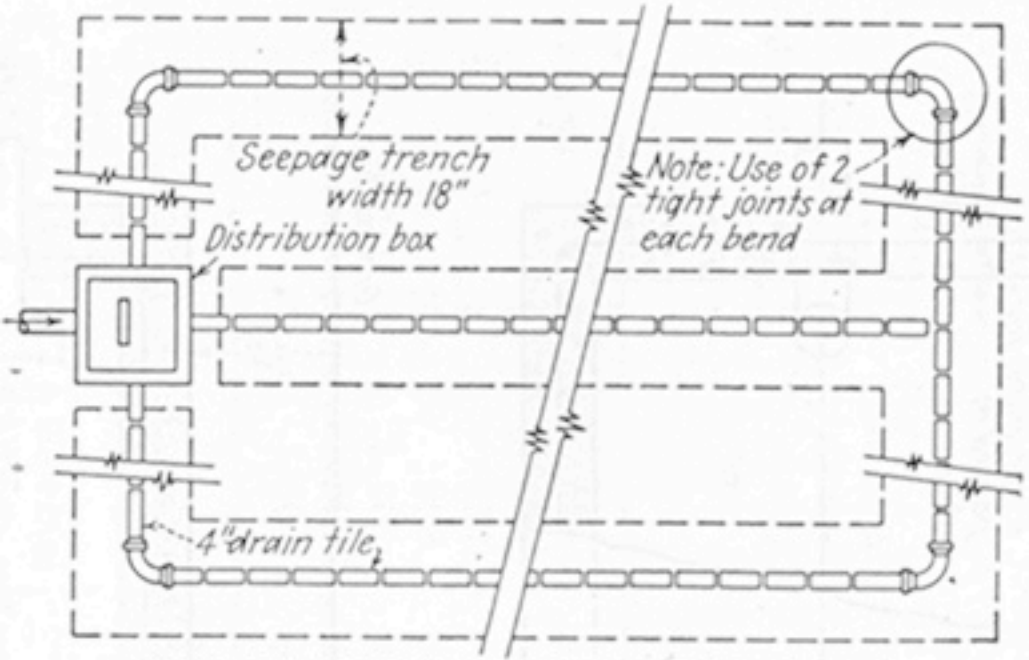
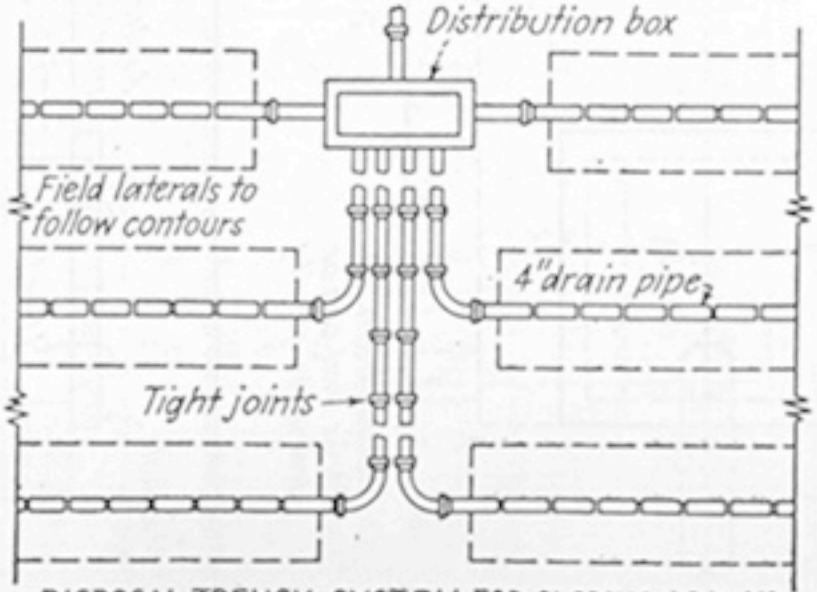


DISPOSAL TRENCH SYSTEM FOR LEVEL GROUND



DISPOSAL TRENCH SYSTEM FOR SLOPING GROUND

Tile Fields

Sub-Surface Disposal

Gravel-filled Trenches

Open-Joint Tiles

Infiltration to Vadose Zone

Biological Slime Formation

Mineral Precipitates, FeS

Release of Gases, H_2S, CH_4

Soil Acceptance Rate:

0.3 to 0.5 gpd/sf

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Sewage Disposal - 1930

U.S. Sewage Disposal (Cities > 100,000 Population)

"Dilution is the Solution to Pollution"

Treatment	Population	%
None, Dilution alone	16,900,000	46.4
Fine Screening, Dilution	8,500,000	23.3
Sedimentation, Dilution	5,700,000	15.6
Trickling Filtration, Dilution	*2,500,000*	*6.9*
Activated Sludge, Dilution	*2,600,000*	*7.1*

14% of population of major cities had biological treatment.

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Karl Imhoff

1906: Taschenbuch der Stadtentwasserung

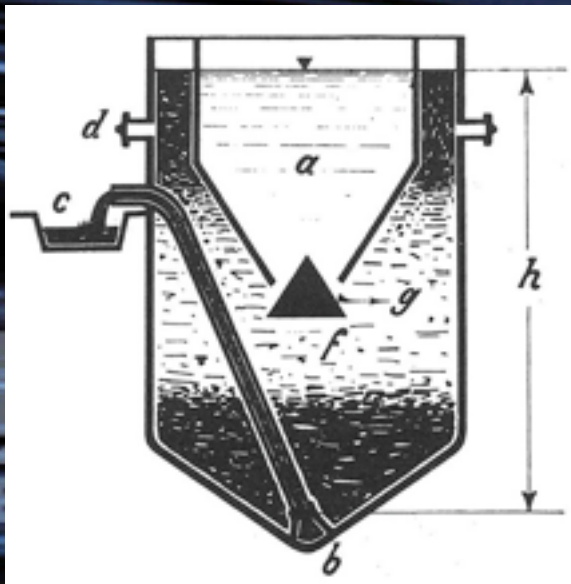
Sewers:Open ditches with concrete slabs

Two-Storied Settling and Digestion Tanks

1913-1934: 70 works constructed, Ruhr River

1929 : Karl Imhoff and Gordon Fair (Harvard)

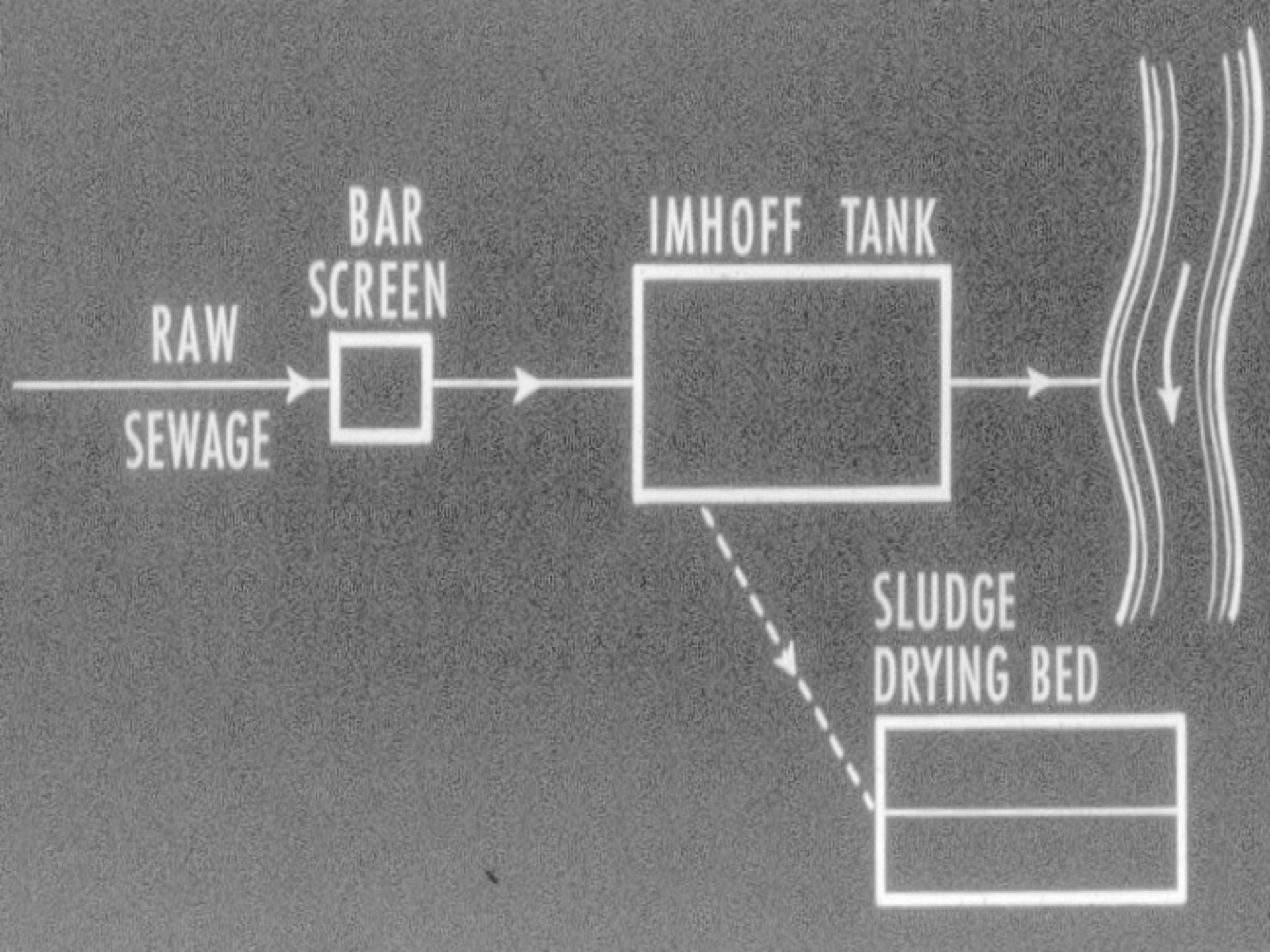
The Arithmetic of Sewage Treatment Works



Imhoff Tank patented in 1906; first operated in 1908

Imhoff Tank Treatment Plant

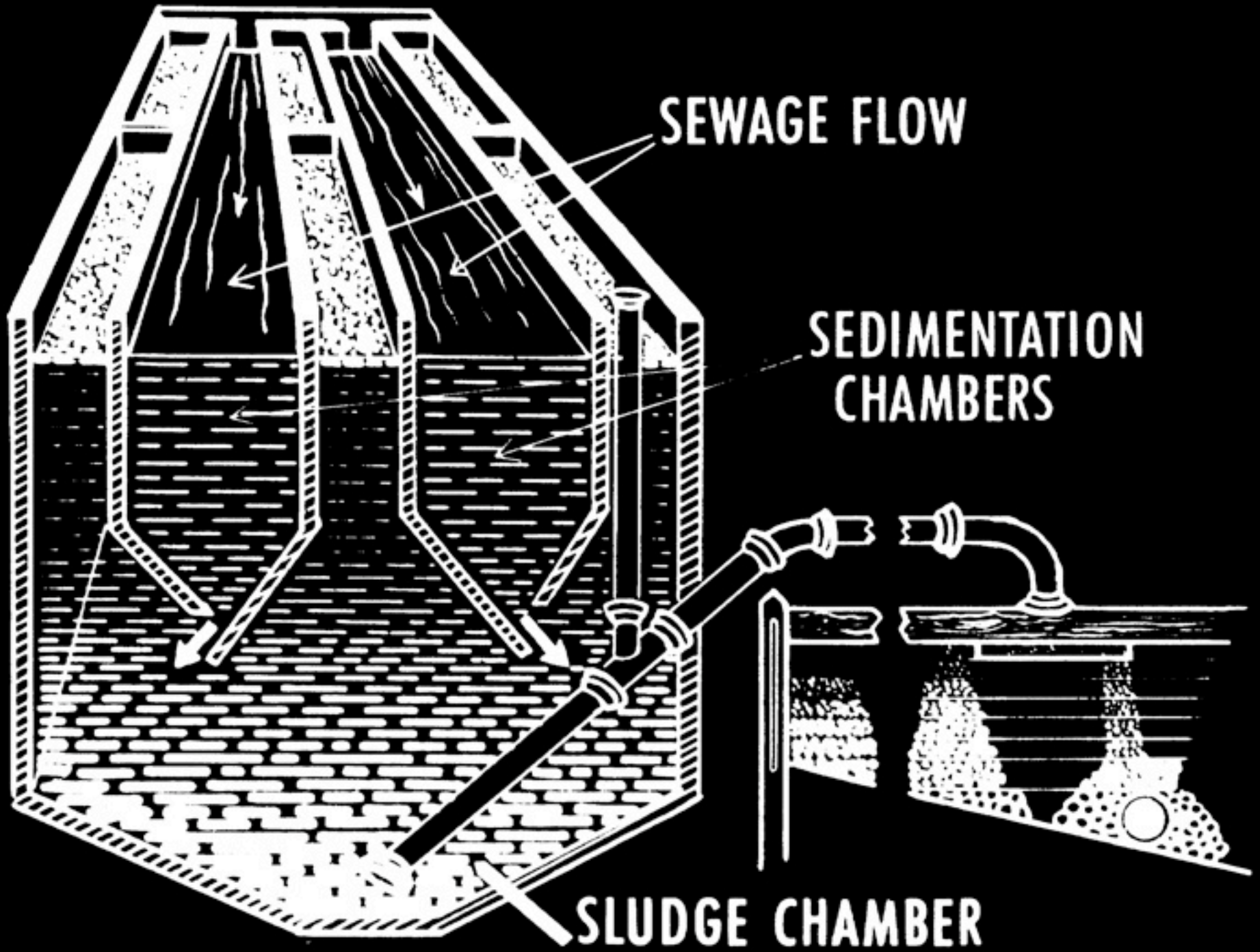
Population: 1000 **40,000 gpd**


RAW
SEWAGE
BAR
SCREEN
IMHOFF TANK
SLUDGE
DRYING BED

Manually-Cleaned Bar Rack

Imhoff Tank

Settling Compartments and Gas Vents


SEWAGE FLOW
SEDIMENTATION CHAMBERS
SLUDGE CHAMBER

Gas Rising from Gas Vent

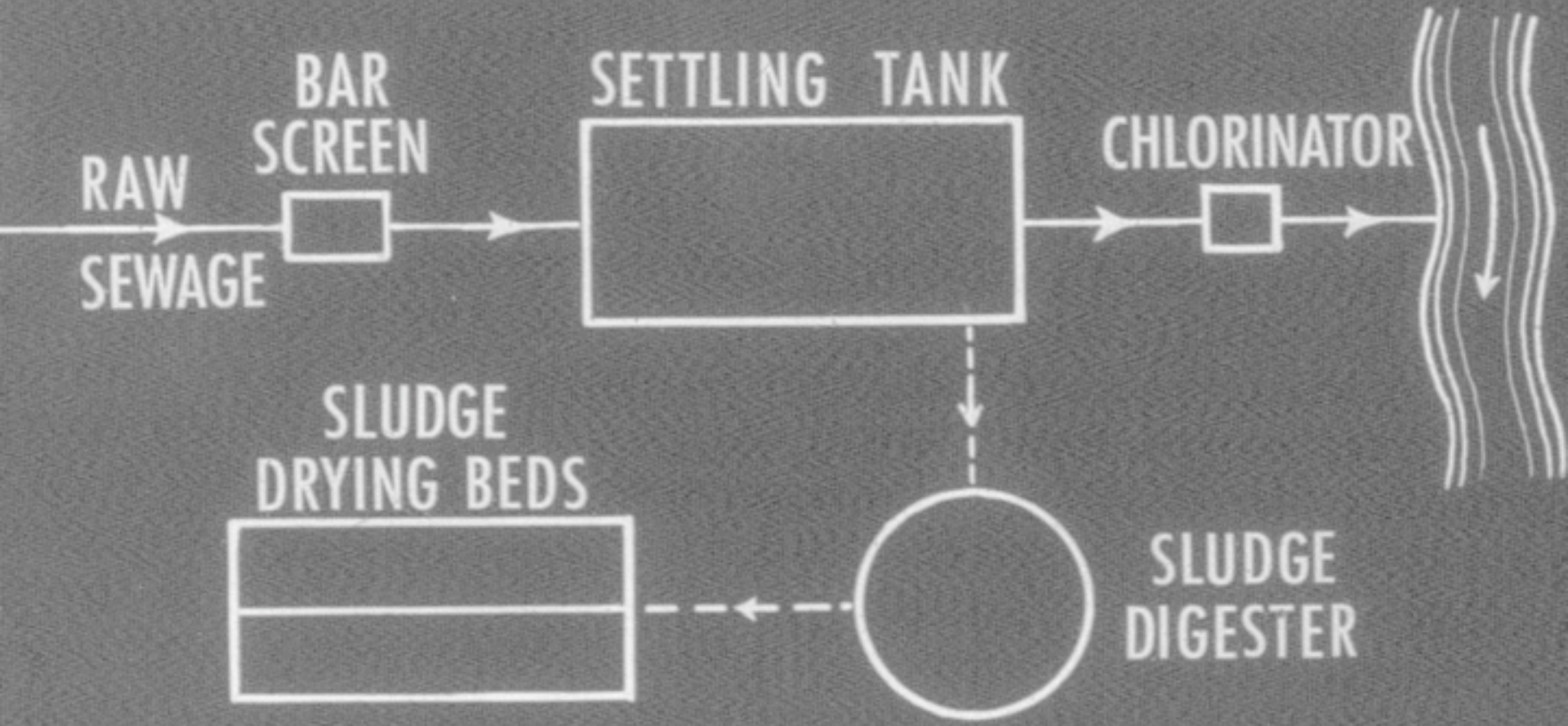
Raw Sludge Drying Beds

Sewage Effluent entering Stream

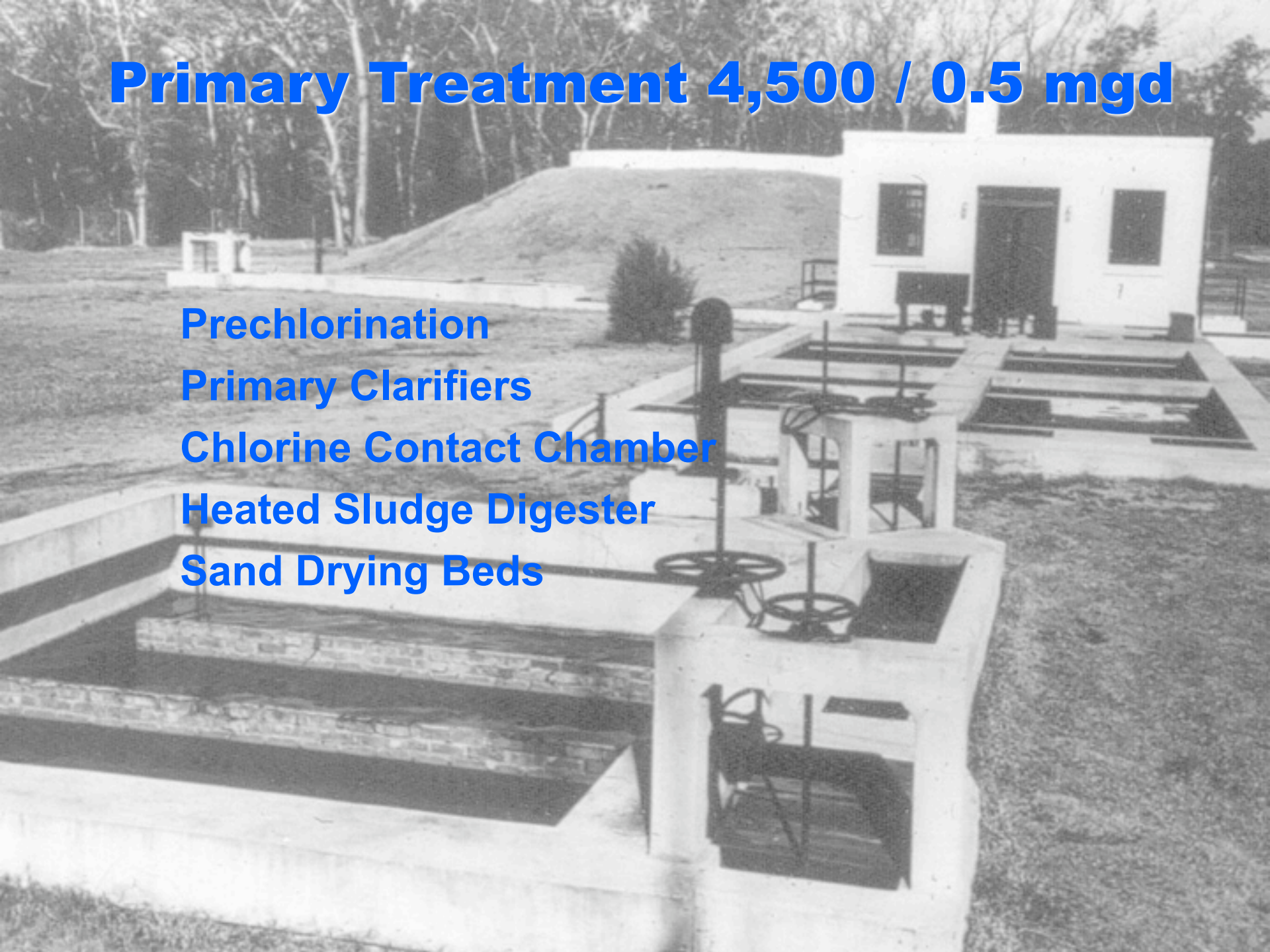
50% Suspended Solids Removal

50% Reduction in Oxygen Demand

PRIMARY SETTLING WITH SEPARATE SLUDGE DIGESTION



Primary Treatment 4,500 / 0.5 mgd



Prechlorination

Primary Clarifiers

Chlorine Contact Chamber

Heated Sludge Digester

Sand Drying Beds

Prechlorination and Sampling

Dual, Manually-Cleaned Bar Screens

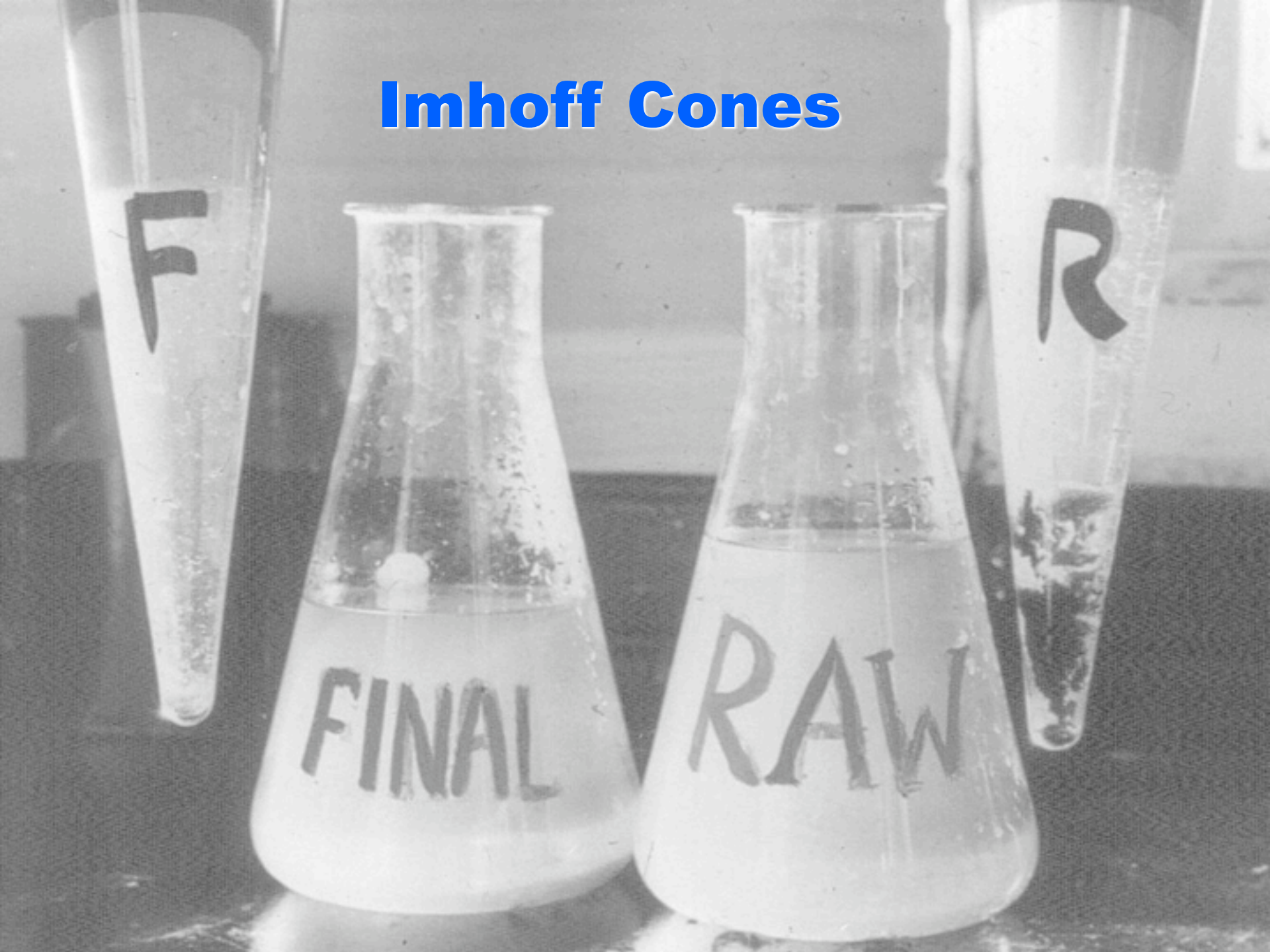
Rectangular, Mechanically-Cleaned Clarifiers

Scum Removal

Chlorine Contact Chamber

Effluent Sampling

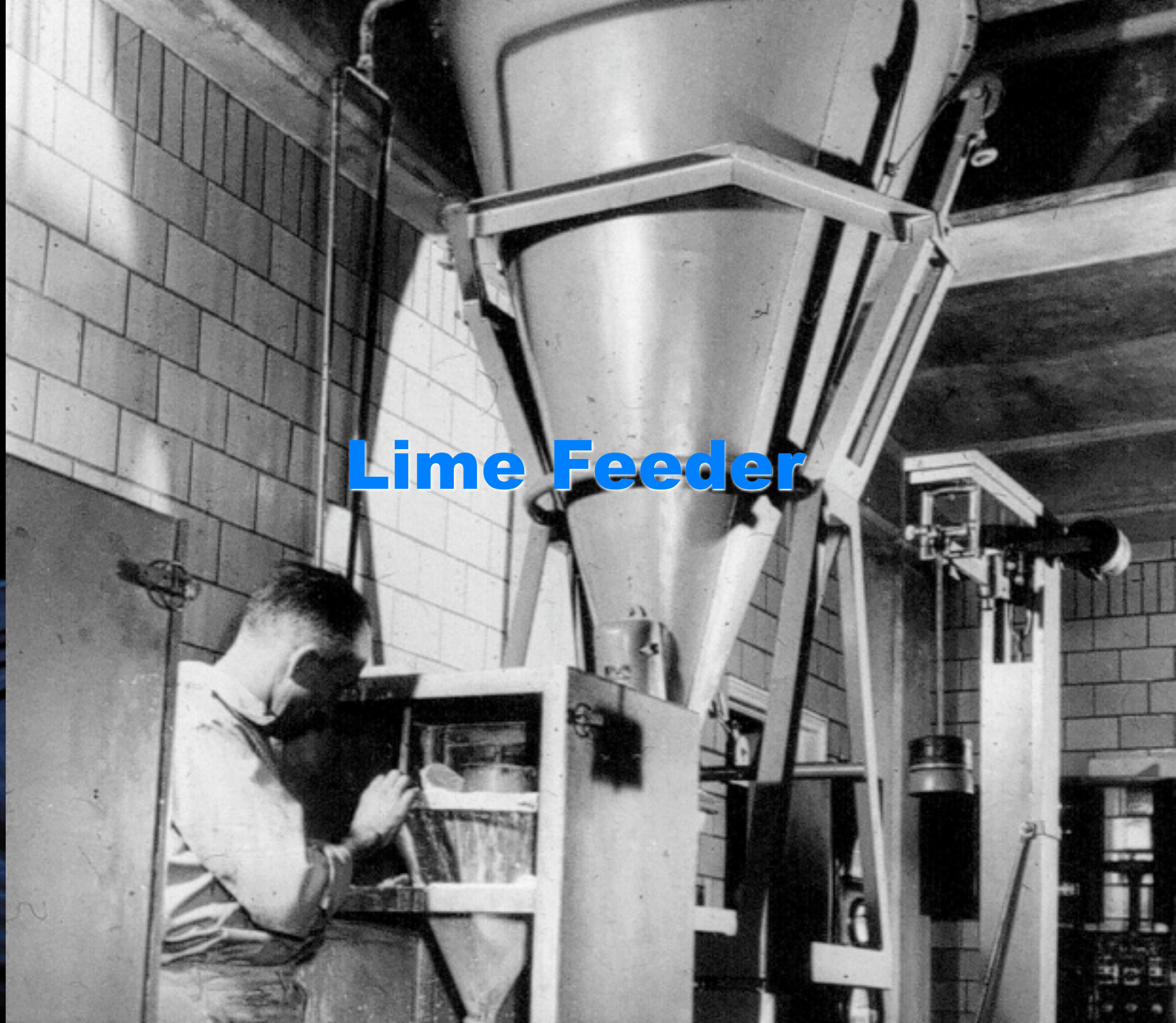
Imhoff Cones



Heated Digester

Floating Cover

Sand Drying Beds

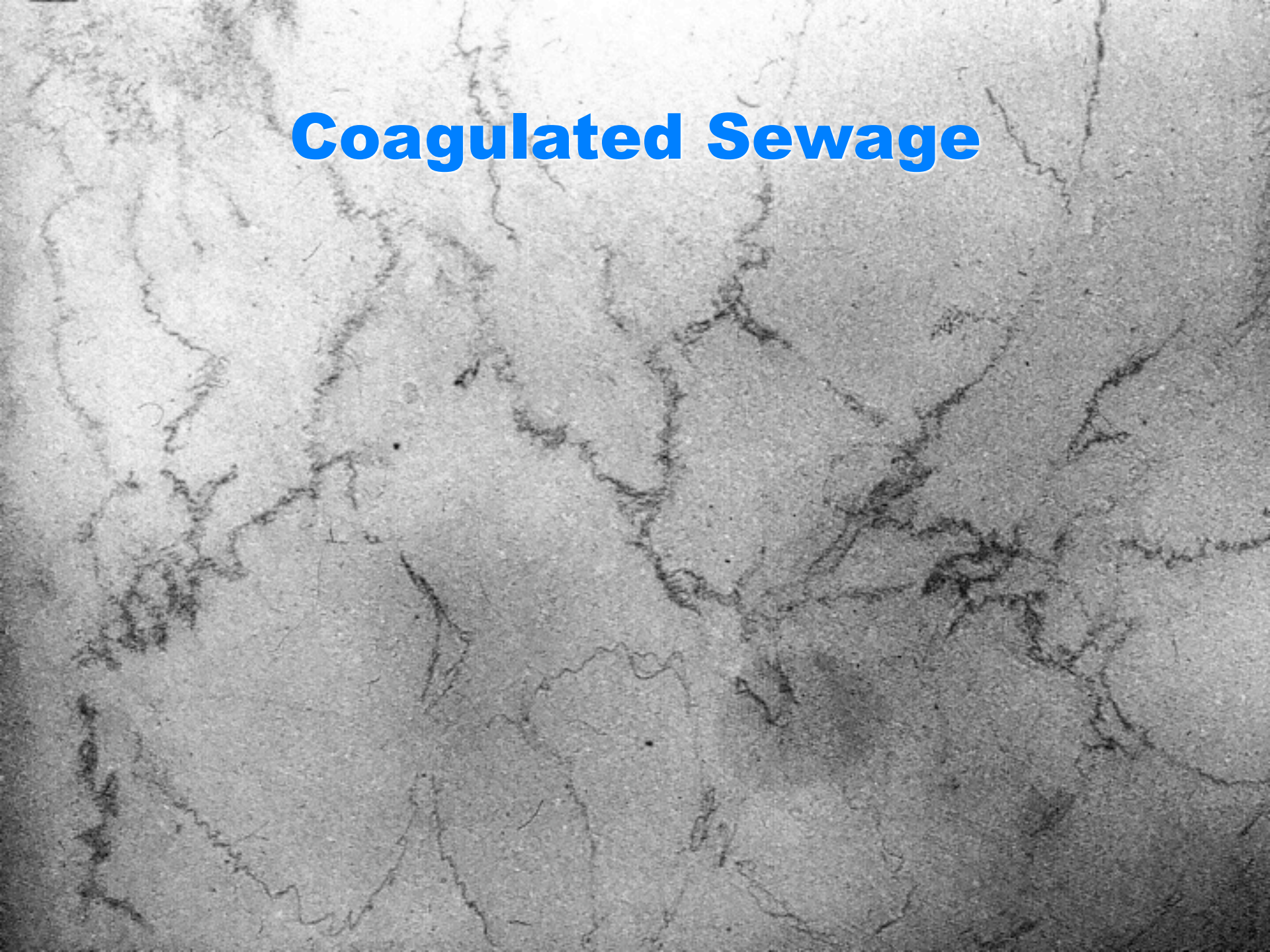

Lime Feeder

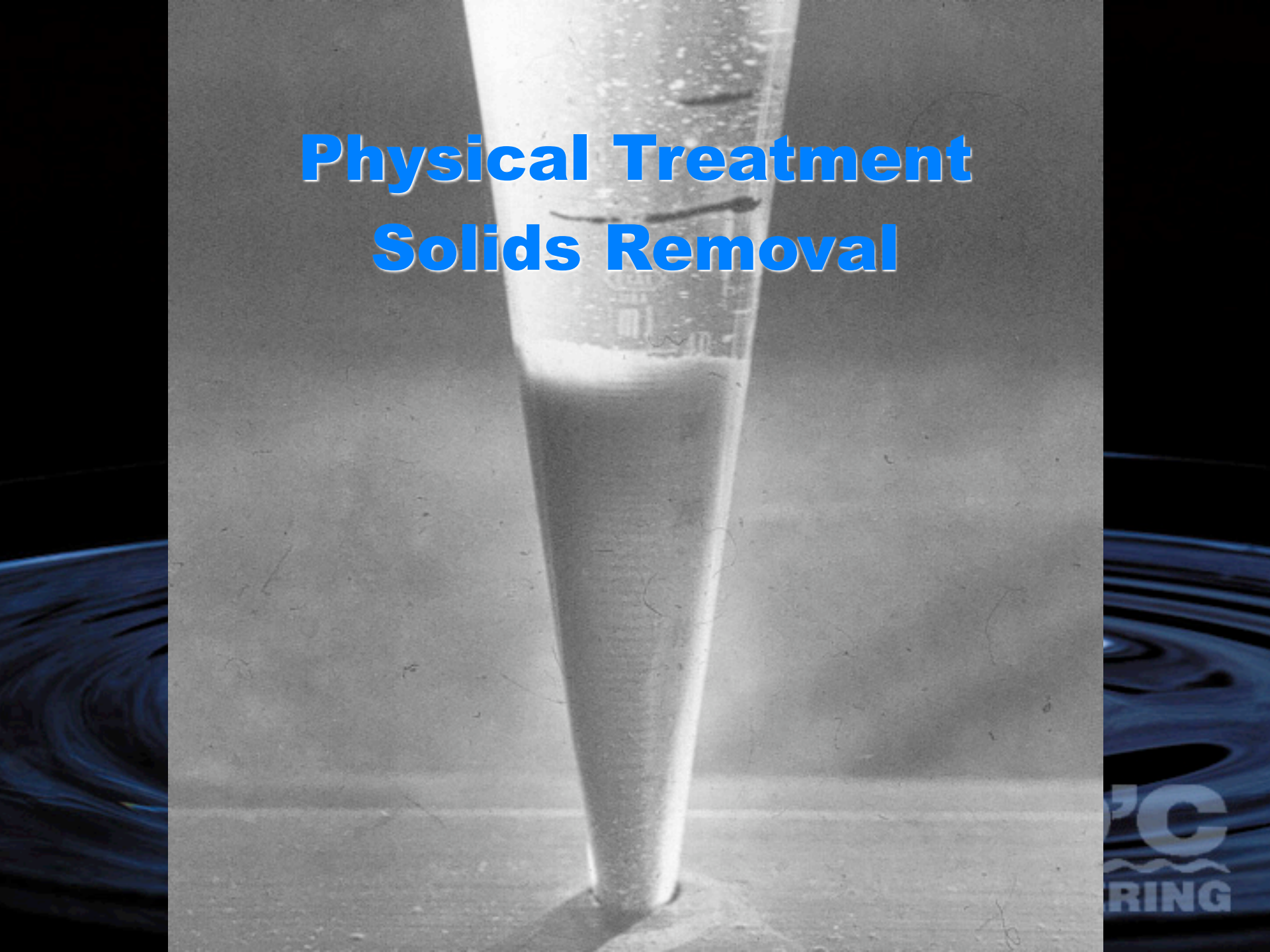
Lime Feed

Ferric Chloride

$FeCl_3$ + Lime Feed

Chemical Treatment Basin


Coagulated Sewage

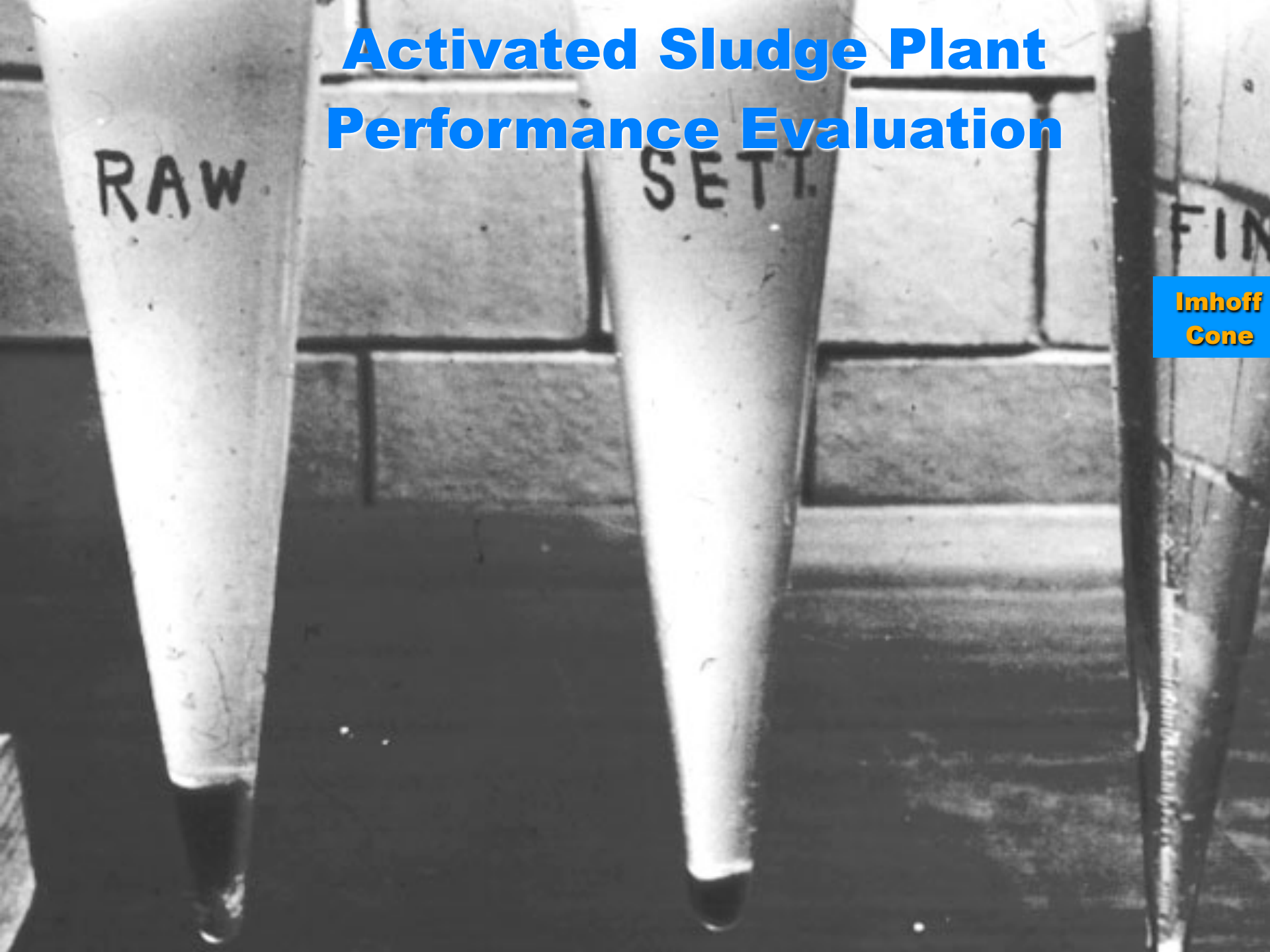

Physical Treatment
Solids Removal

Trickling Filter

Popular with Birds - “BOD flies away”

Aeration Tanks
208

Activated Sludge Plant Performance Evaluation

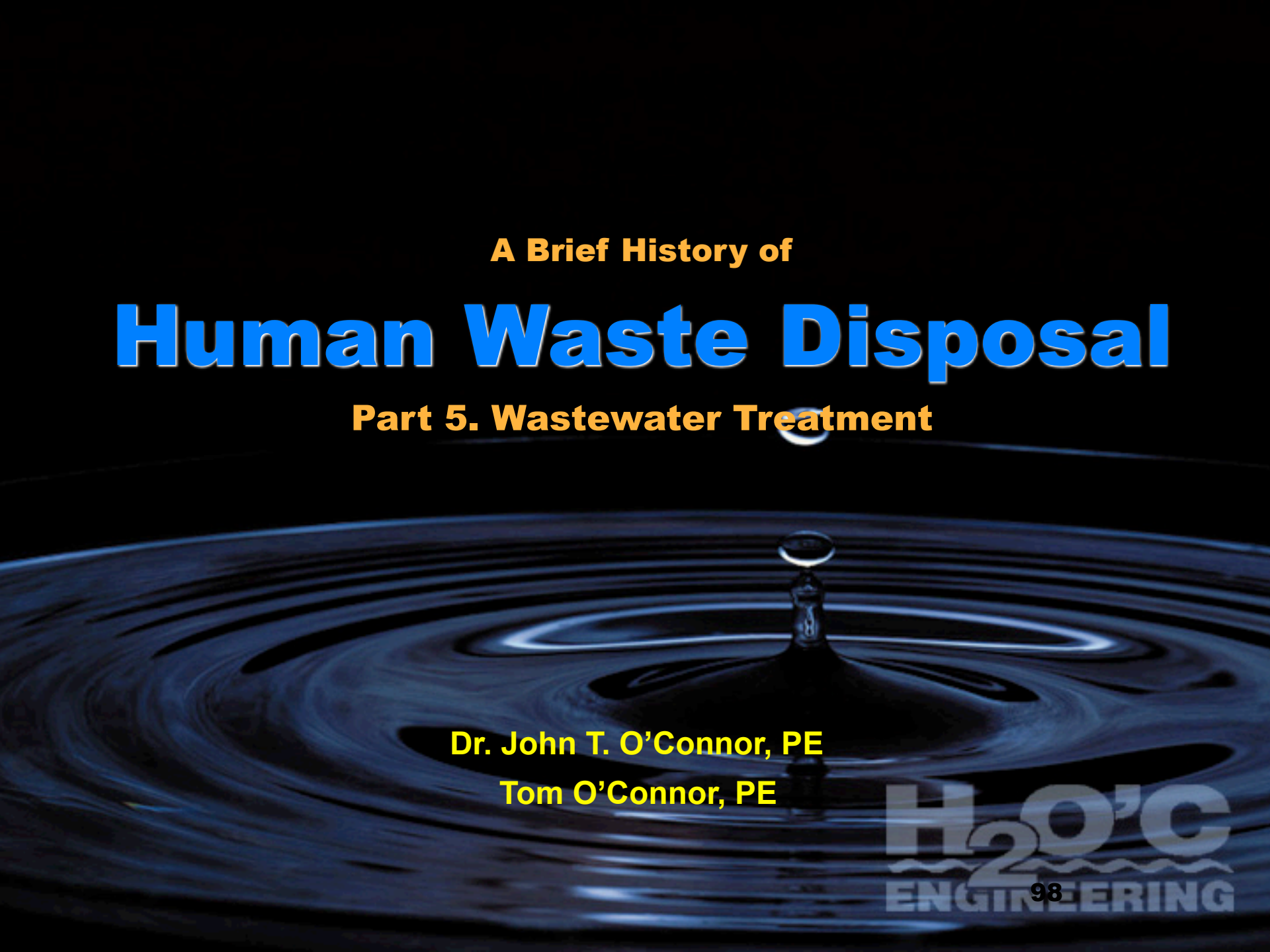


Community Water Supply - Wilder, TN. - 1942

A Brief History of

Human Waste Disposal

Part 5. Wastewater Treatment



Dr. John T. O'Connor, PE

Tom O'Connor, PE

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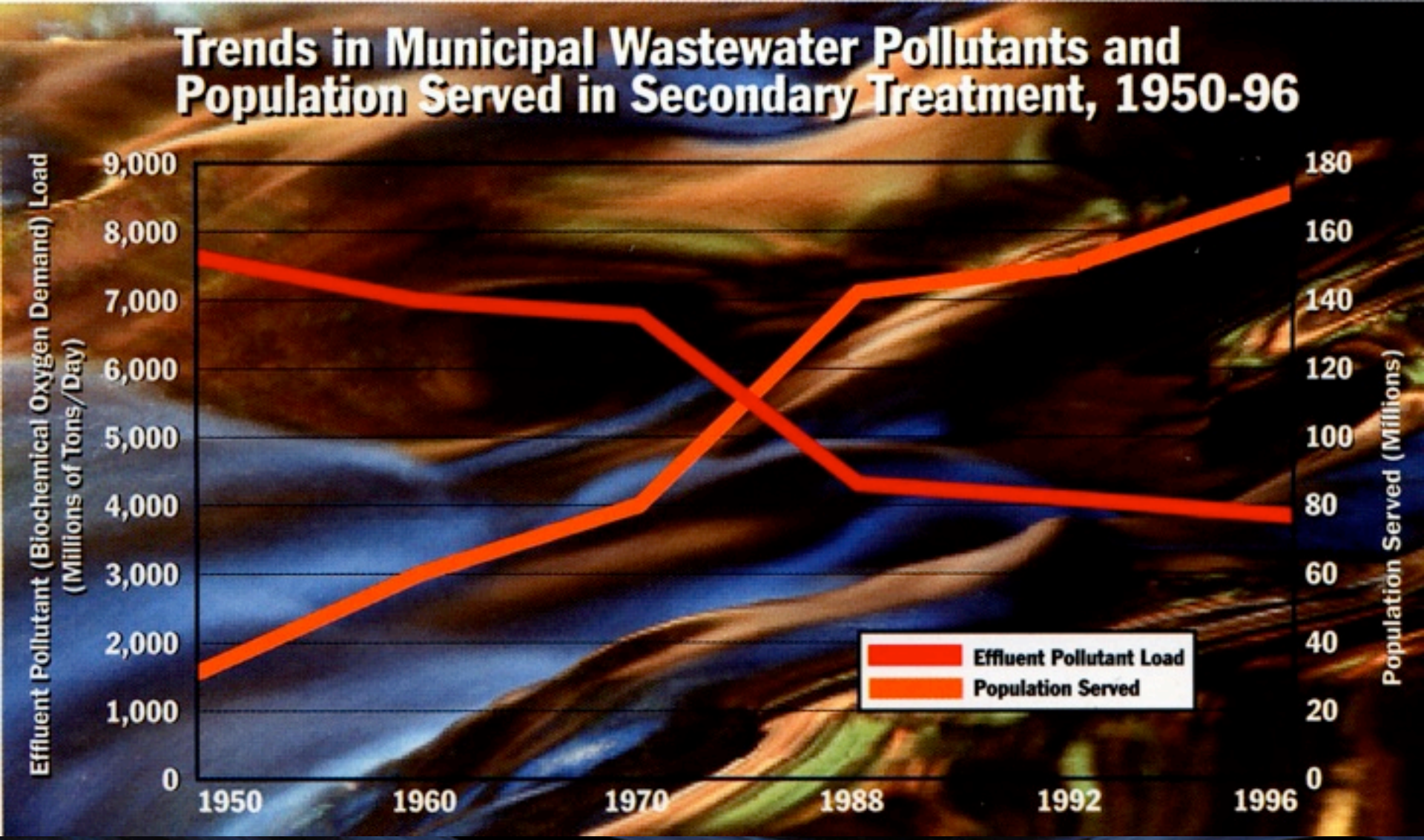
Trends in Municipal Wastewater Pollutants and Population Served in Secondary Treatment, 1950-96



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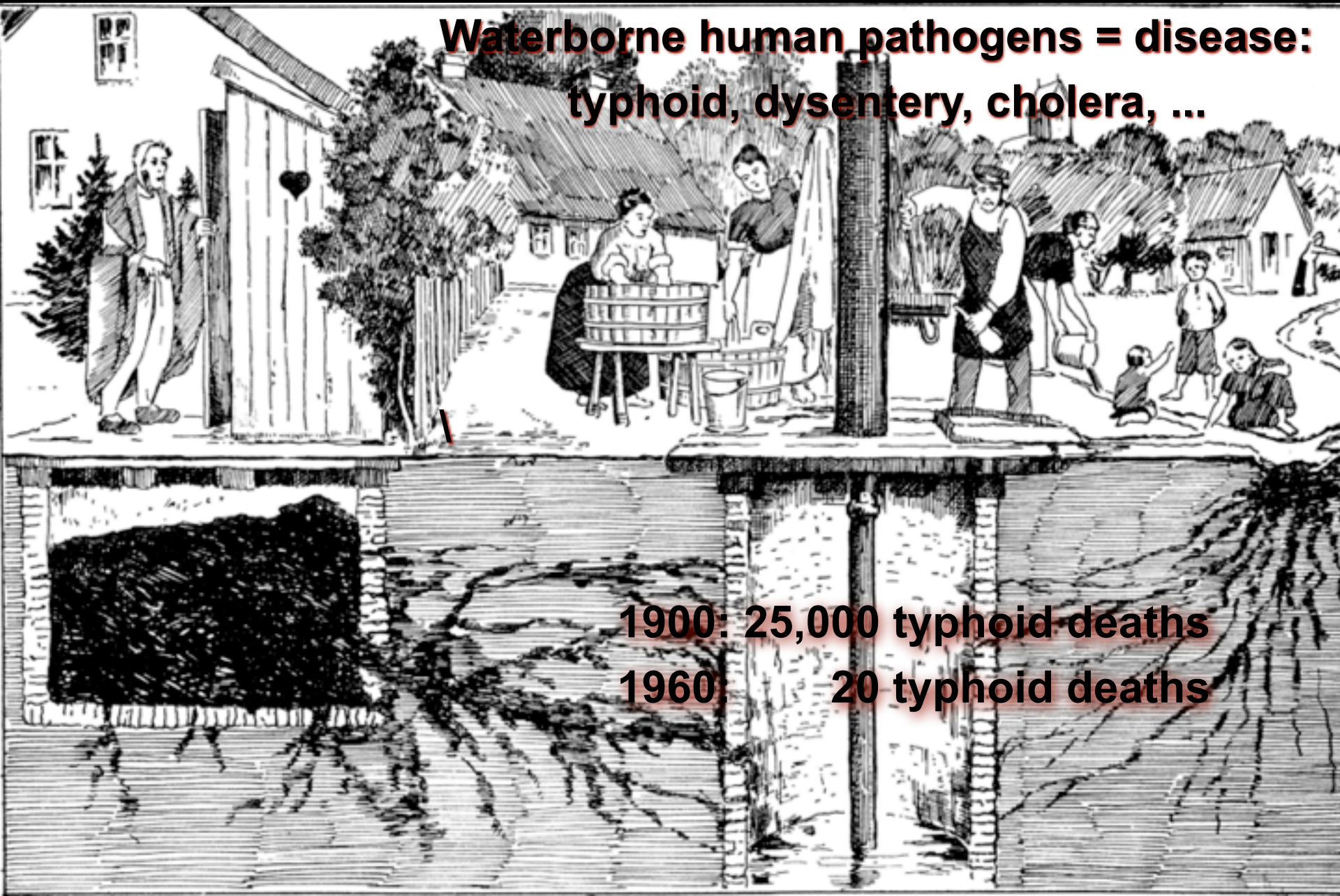
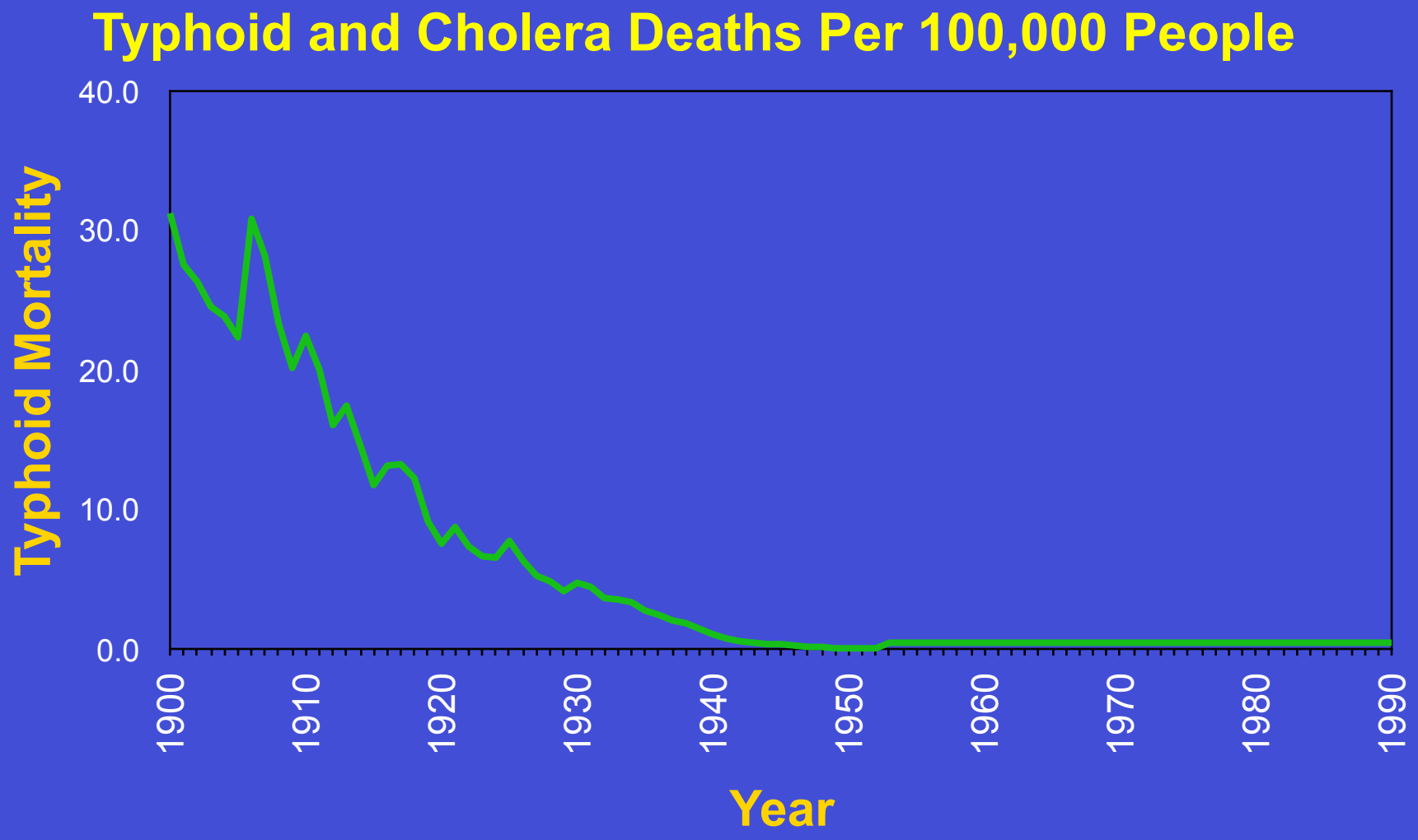
Pollution Control Legislation

1948	Water Pollution Control Act
1956	Fed. Water Pollution Control Act
1961	Amendments to FWPCA
1965	Water Quality Act
1966	Clean Water Restoration Act
1970	USEPA Established
1972	FWPCA Approved
1981	Construction Grants Amendments
1987	Water Quality Act

Why Disinfect Wastewater?



History of Chlorination in the U.S.



Why Disinfect Wastewaters?

2. Environmental Concerns

Cl_2

ClO_2

O_3

UV

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LA Fish, Crab, Eel, Stingray Kill

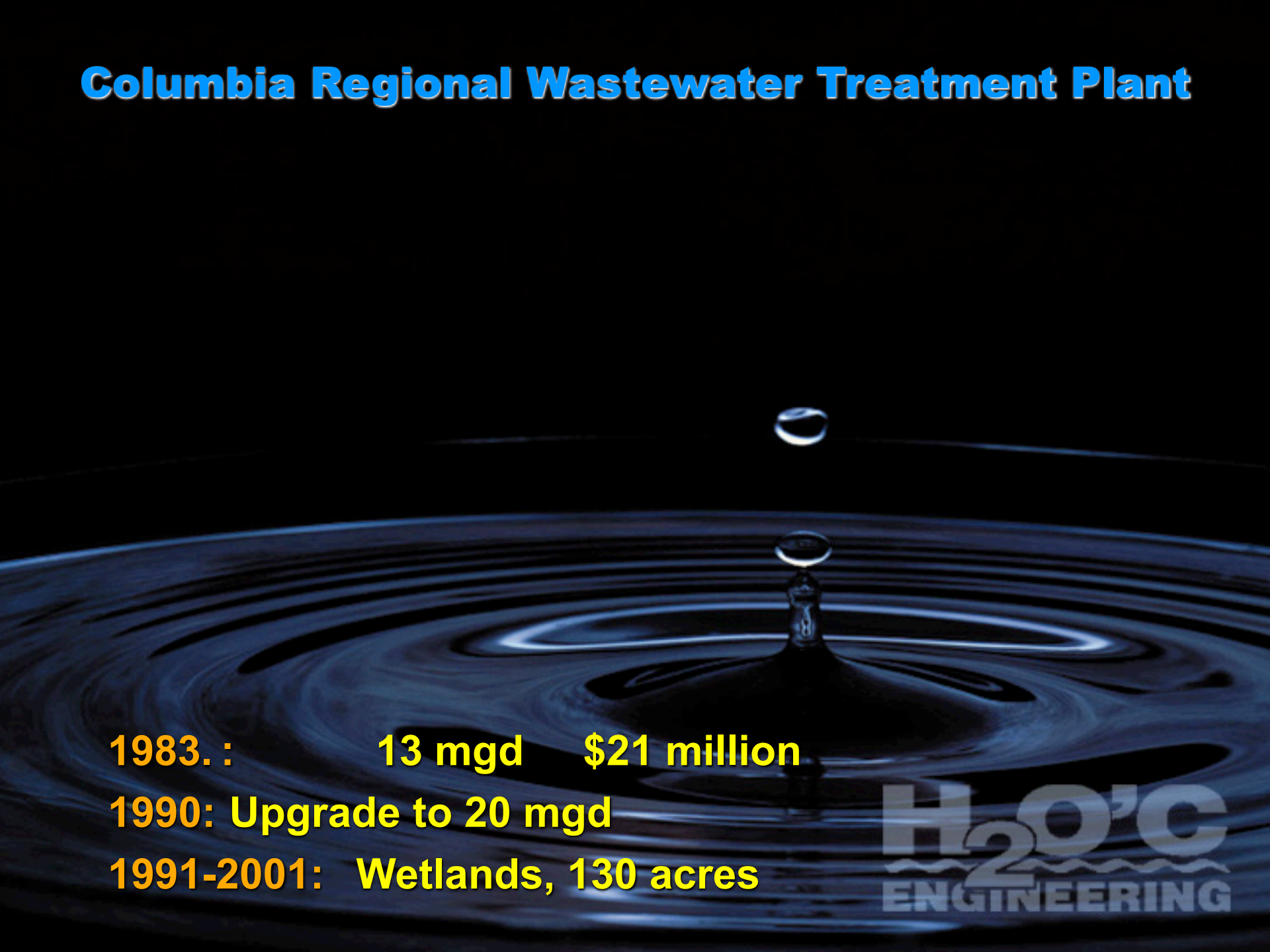
Plaquemines Parish, September, 2010

LA Fish, Crab, Eel, Stingray Kill

Plaquemines Parish, September, 2010

Kill attributed to high temperatures and
oxygen depletion;
farm runoff, not BP

Columbia Regional Wastewater Treatment Plant



1983. : 13 mgd $21 million

1990: Upgrade to 20 mgd

1991-2001: Wetlands, 130 acres

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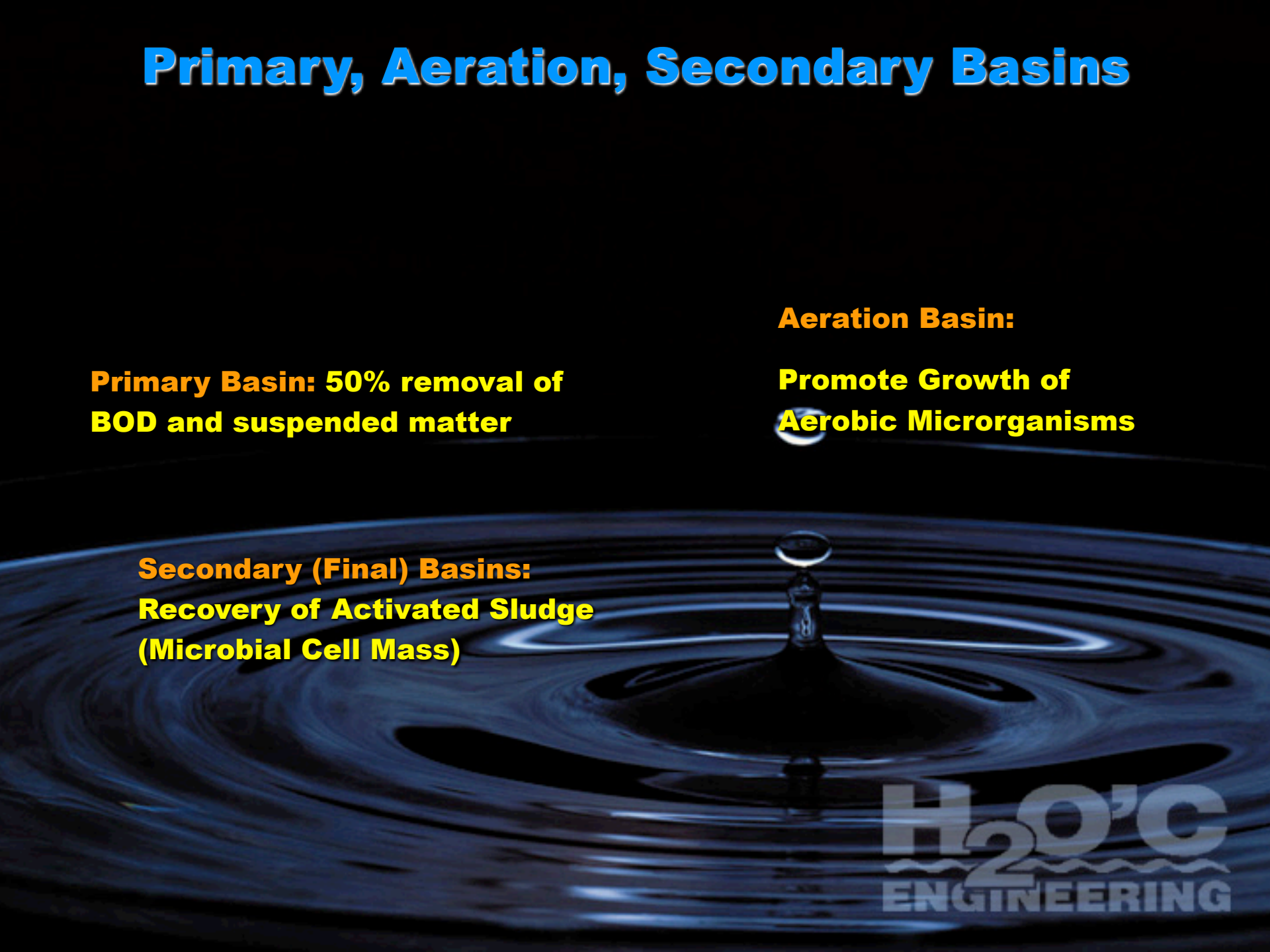
Primary, Aeration, Secondary Basins

Primary Basin: 50% removal of BOD and suspended matter

Aeration Basin:

Promote Growth of Aerobic Microrganisms

Secondary (Final) Basins:
Recovery of Activated Sludge (Microbial Cell Mass)



Sludge Treatment and Disposal

Covered, Heated
Anaerobic Digesters

Digester Gas runs generator
and provides heat

Digested Sludge is applied
to farmland

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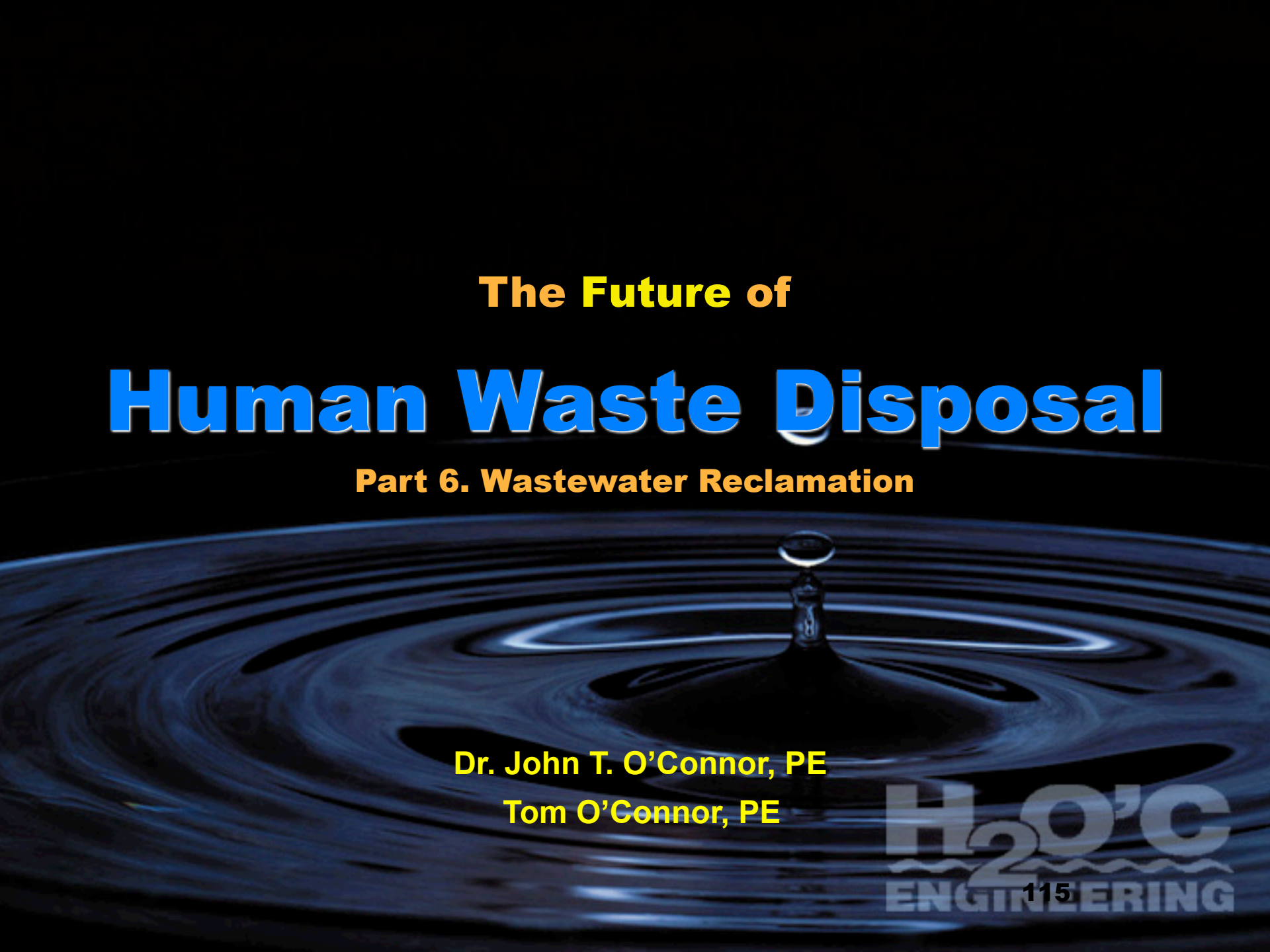
Tertiary Treatment



The Future of

Human Waste Disposal

Part 6. Wastewater Reclamation

Dr. John T. O'Connor, PE

Tom O'Connor, PE

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Water Use ⇒ Wastewater

Population Growth x Water Use (130 gpcd, max. month)

Urban Sprawl ⇒ sewer extensons, irrigation of suburbs

Groundwater depletion; drought; consumptive water use

Growing Water Shortages

New Water Sources?

U.S.: 22,000 POTW (98% municipally-owned) ⇒ 35 billion g/d

1 billion g/d (3%) of treated WW ⇒ parks, golf courses, ...

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U.S. Population Growth

	Population, millions	Life Expectancy, years
1933:	125	-
2010:	***310***	***78***
2025:	357	80
2050:	439	83

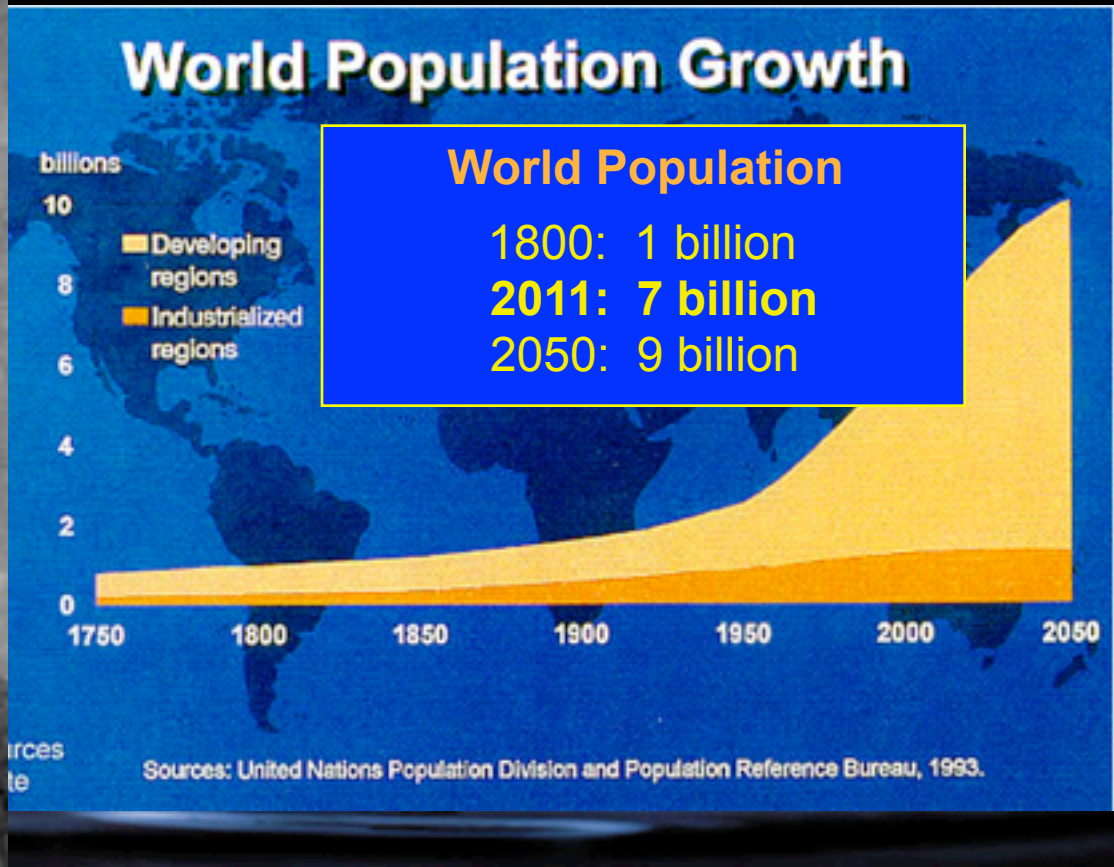
U.S. Population Increase: 3 million/year

New Missouri every 2 years

(Anglican) Reverend Thomas Robert Malthus, 1766-1834

"The power of population is indefinitely greater than the power in the earth to produce subsistence for man".
An Essay on the Principle of Population

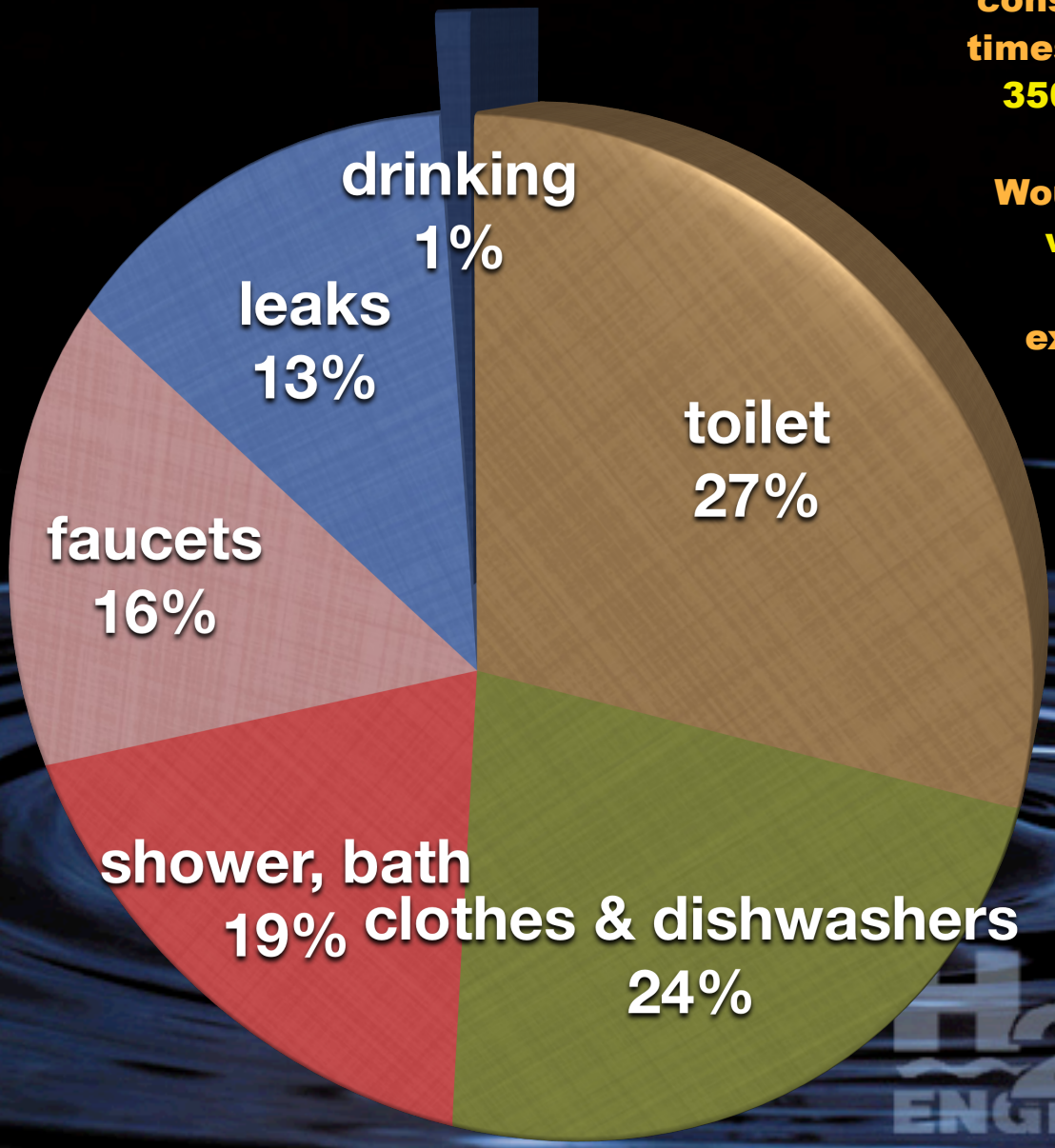
If Malthus is wrong, then will human population growth go on forever?



Suburban homeowners are ‘grass farmers’

60% of water use is outdoors; **only 40% indoors**

% Daily Indoor Water Use



Some households consume two to five times as much as the 350 gpd average?

Would progressive water pricing discourage excessive use?

Managing Wastewater Costs

2. Reduce Hydraulic Loadings

Mandate efficiency of toilets, showers, faucets

Advocate Gray Water use for lawn, gardens, toilets

U.S. Suburban Household Water Use

Average Day: 350 gallons

Toilet flushing: 100 gallons

Gallons per flush: 3.5, 1.6, 1.28, 1.0

Federal Water Efficiency Standards (1992)

Showerheads: 2.5 gallons per minute

Faucets: 2.5 gallons per minute

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Managing Wastewater Costs

2. Water Conservation Programs

Offer Financial incentives to install water-efficient toilets

Pass Municipal ordinances allowing watering only on certain days

Ban ornamental fountains unless they run on re-circulated water

Require homes to have low-flow shower heads and faucet aerators

Recycle Gray Water

"If it's yellow,
let it mellow;
if it's brown,
flush it down."

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When freshwater gets scarce … utilize ‘toilet to tap’, a.k.a.

Wastewater Reclamation & Reuse

California State Department of Health

permits use of reclaimed wastewater for:

- ☑ agricultural irrigation of over *20 food crops**,
- ☑ landscape parks, playgrounds, golf courses,
- ☑ restricted recreational impoundments,
- ☑ groundwater recharge to *domestic water supply areas*

*Apples, Grapes, Asparagus, Lettuce, Avocados, Maize, Barley, Peaches, Beans, Peppers,Broccoli, Pistachios, Cabbage, Plums, Cauliflower, Squash, Celery, Sugar Beets, Citrus, Wheat

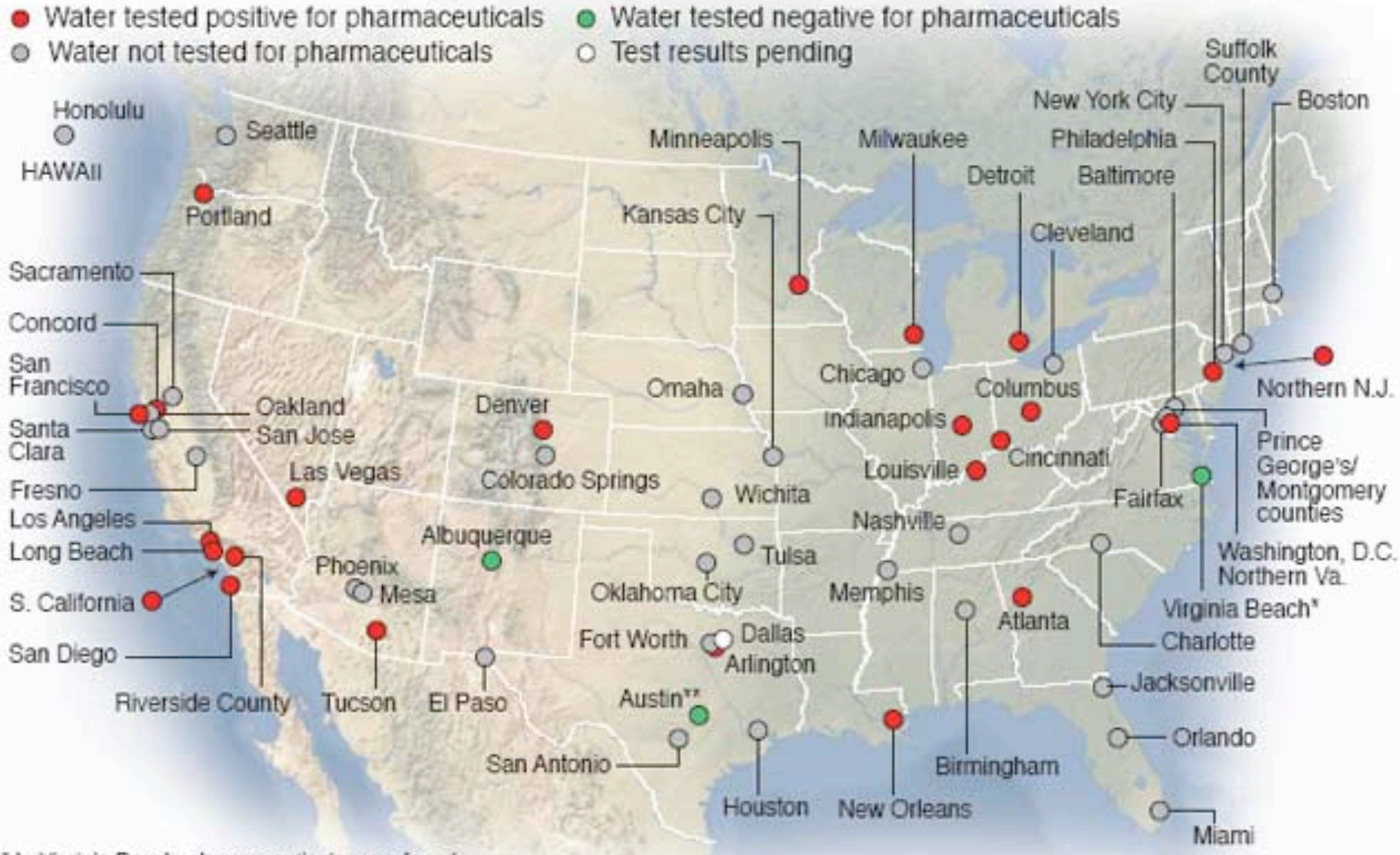
Emerging Health Concerns

- **pharmaceuticals:** N-nitrosodimethylamine (NDMA), 1,4-dioxane, bisphenol A, alkylphenol polyethoxy carboxylates (APECs), dioxin, disinfection by-products, ...
- **cosmetics, hormones, nanomaterials**
- **endocrine disruptors,** a class of compounds that perturb the normal functioning of endocrine systems including those that affect growth, reproduction and behavior.

Partial removal requires capital, energy-intensive processes:

(GAC adsorption; ozonation; micro-, ultra-, nano-filtration; reverse osmosis; membrane bioreactors; advanced oxidation (hydrogen peroxide - UV)

Pharmaceuticals in drinking water



* In Virginia Beach, pharmaceuticals were found in source water but not in treated drinking water.
** Drinking water in Austin, Texas, was tested for only one prescription drug, a synthetic birth control chemical.

NOTE: All places include some surrounding areas except: Albuquerque, N.M.; Arlington, Texas; Fresno, Calif.; Long Beach, Calif.; Los Angeles; Memphis, Tenn.; New Orleans; New York City; and Orlando, Fla.

SOURCES: Drinking water providers' responses to Associated Press questions; AP review of scientific literature.

AP

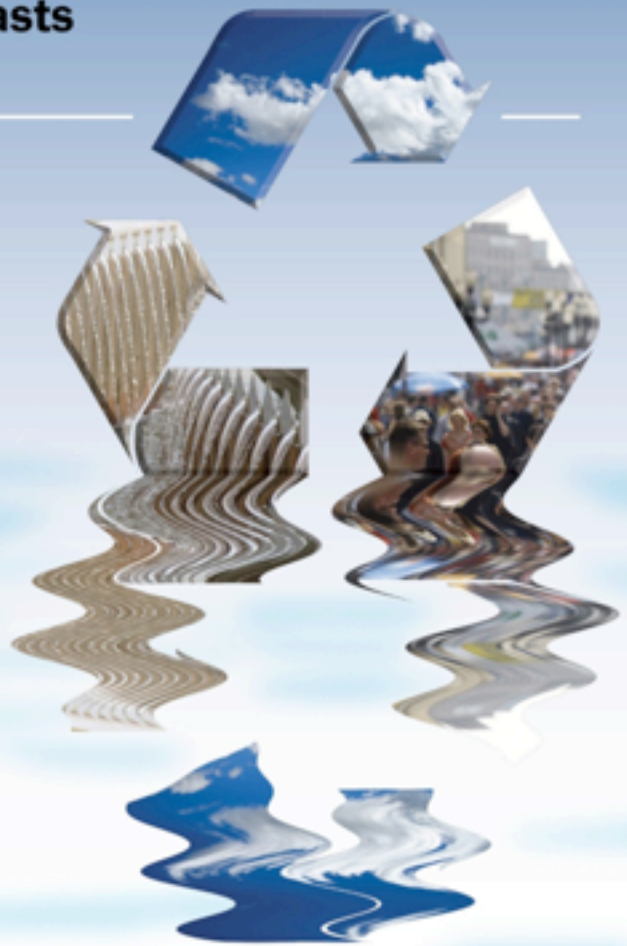
Orange County, CA Water District

'Indirect Potable Water Reuse'

70 mgd - Groundwater Replenishment System

Municipal Water Reuse Markets 2010

Analysis, forecasts and inventory



Global Water Intelligence

A Global Water Intelligence publication

www.globalwaterintel.com

Produced in collaboration with PUB Singapore

PUB

"NEW REVENUE STREAM SPRINGS UP "

"WATER REUSE MARKET SET FOR EXPLOSIVE GROWTH"

"We will drink more reclaimed water - indirectly."

"Ultrafiltration, reverse osmosis and ultraviolet disinfection - have become cheaper and more effective."

"Recycling water seems as natural as any other recycling."

"... water reuse can be an essential part of sustainable cities".

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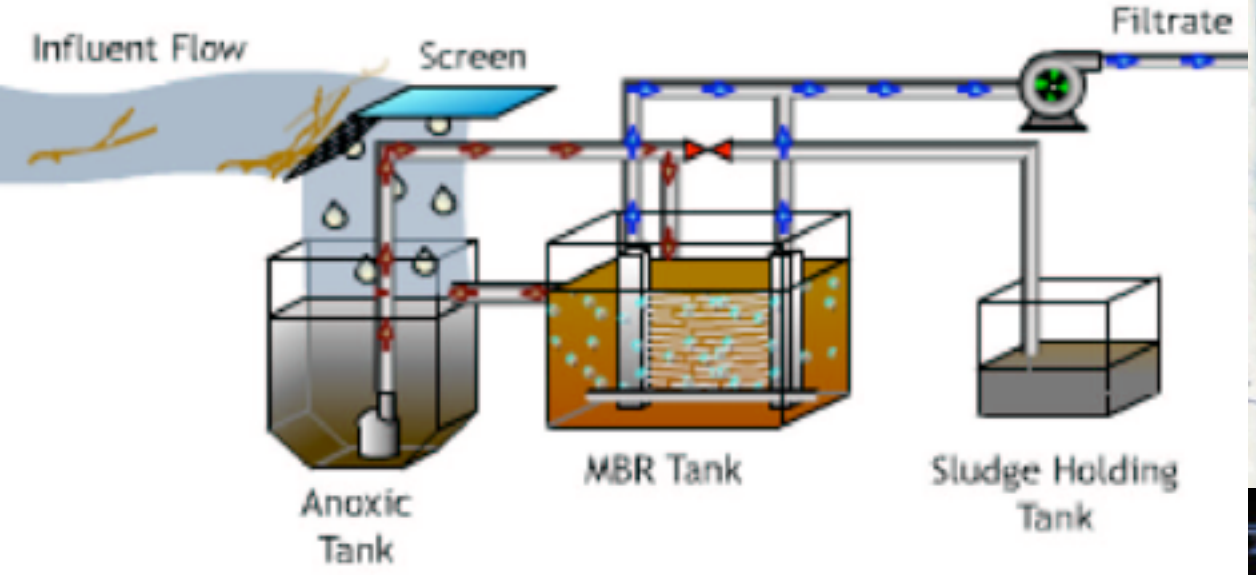
Water Reuse will be Beautiful

KCMO Symbol

Tapping into Sewers

'Sewer Mining' for 'Brown Gold'

Membrane Bioreactors



Requires Chemical Control of Membrane Fouling

Membrane Module

Sewer Mining?

Padlock your manholes?

Membrane Bioreactors (MBR)

membranes immersed into highly concentrated mixed liquor suspended solids

Hydraulic Retention Time: 4-8 hours; 25% conventional footprint

Solids Retention Time: 10- 365 days; 20% conventional sludge yield

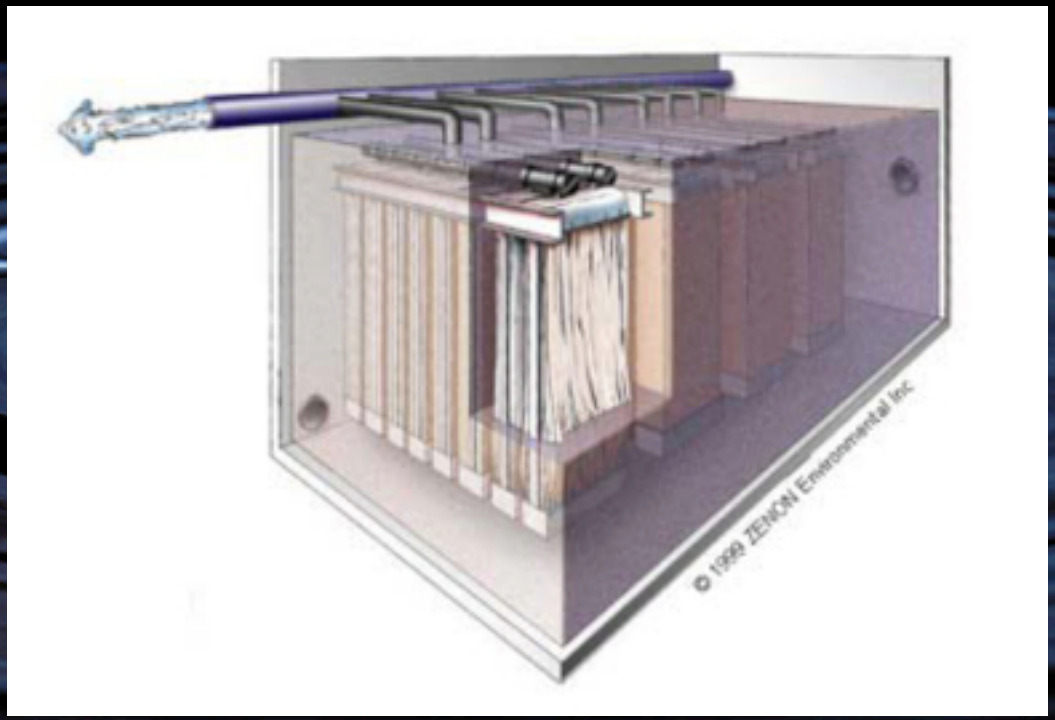
MLSS: 10,000 - 15,000 mg/l

Modular: small scale

Effective organism removals

Removal of nutrients

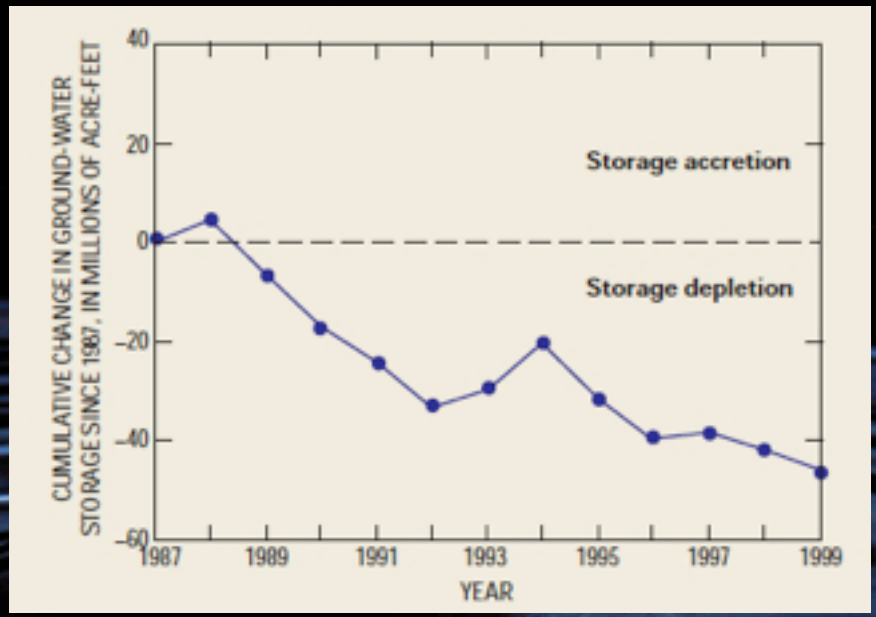
Reuse of product water

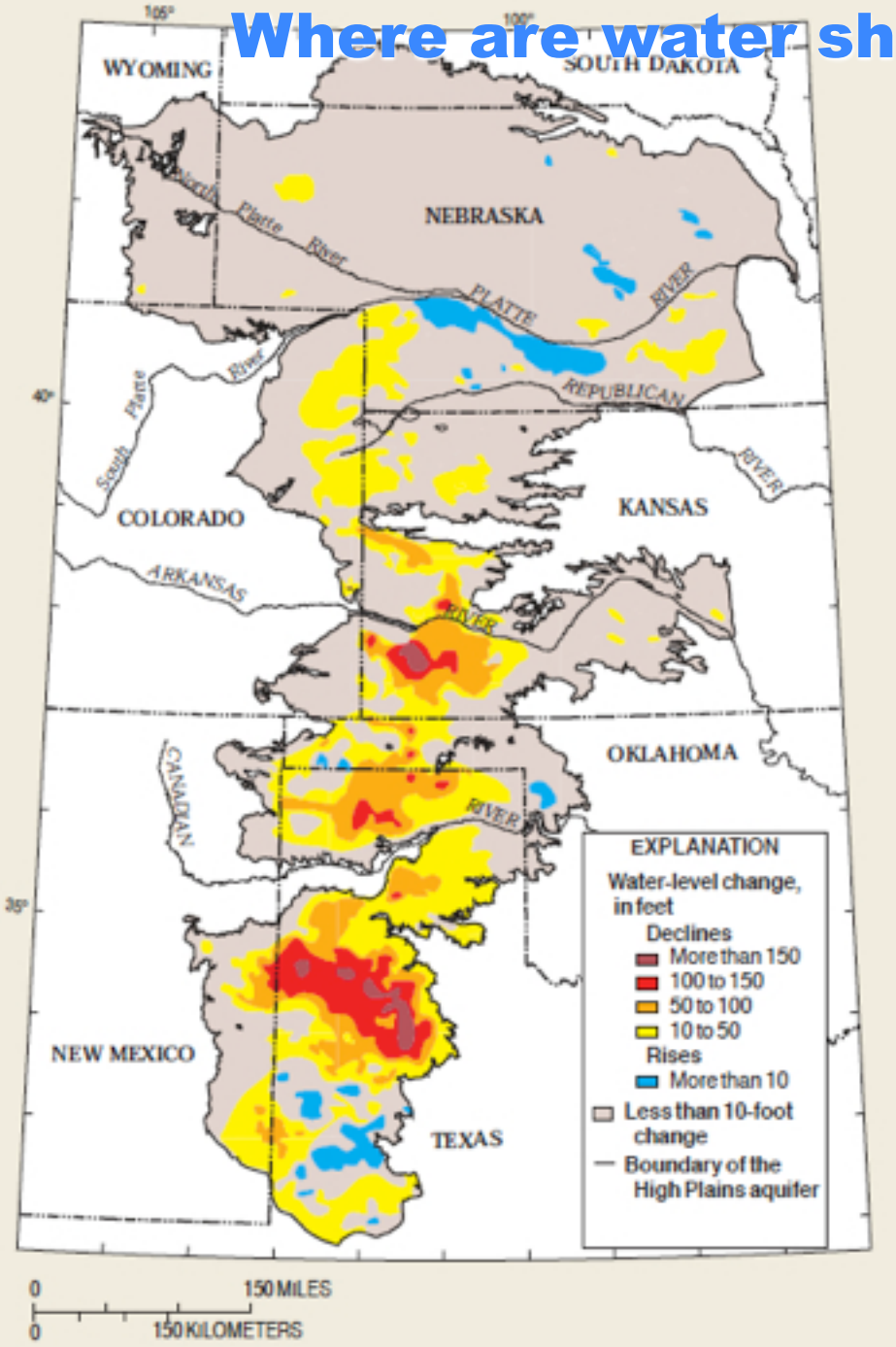


Where are water shortages developing?

High Plains Aquifer:

- water-level declines > 150 feet
- 220 million acre feet removed





Where is Reclamation Occurring?

CA, FL, TX, AZ, NM, NE, CO, GA, WA, VA, NY, MA

Orange County Water District
Central/West Basin
Metropolitan Water District
San Jose
Los Angeles Co Sanit District
San Diego County
Irvine Ranch
Dublin San Ramon
East Bay Municipal Utility District
Orlando
Scottsdale
Phoenix

San Antonio
El Paso
Tarrant Regional
St. Petersburg
Pinellas County
King County (WA)
Austin
Santa Rosa
UOSA (VA)
Southwestern Nevada Water Authority/
Las Vegas Valley Water District

Foxboro, MA

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0.25 mgd used for toilet flushing

The Future of Waste Management ?

- energy, chemicals, and materials costs ⇒ *rate increases*
- reduction of federal subsidies, grants ⇒ *rate increases*
- consolidation of W & WW systems ⇒ *staff reductions*
- reclamation of wastewater ⇒ *reuse, groundwater recharge*
- conservation ordinances ⇒ *water use reductions*